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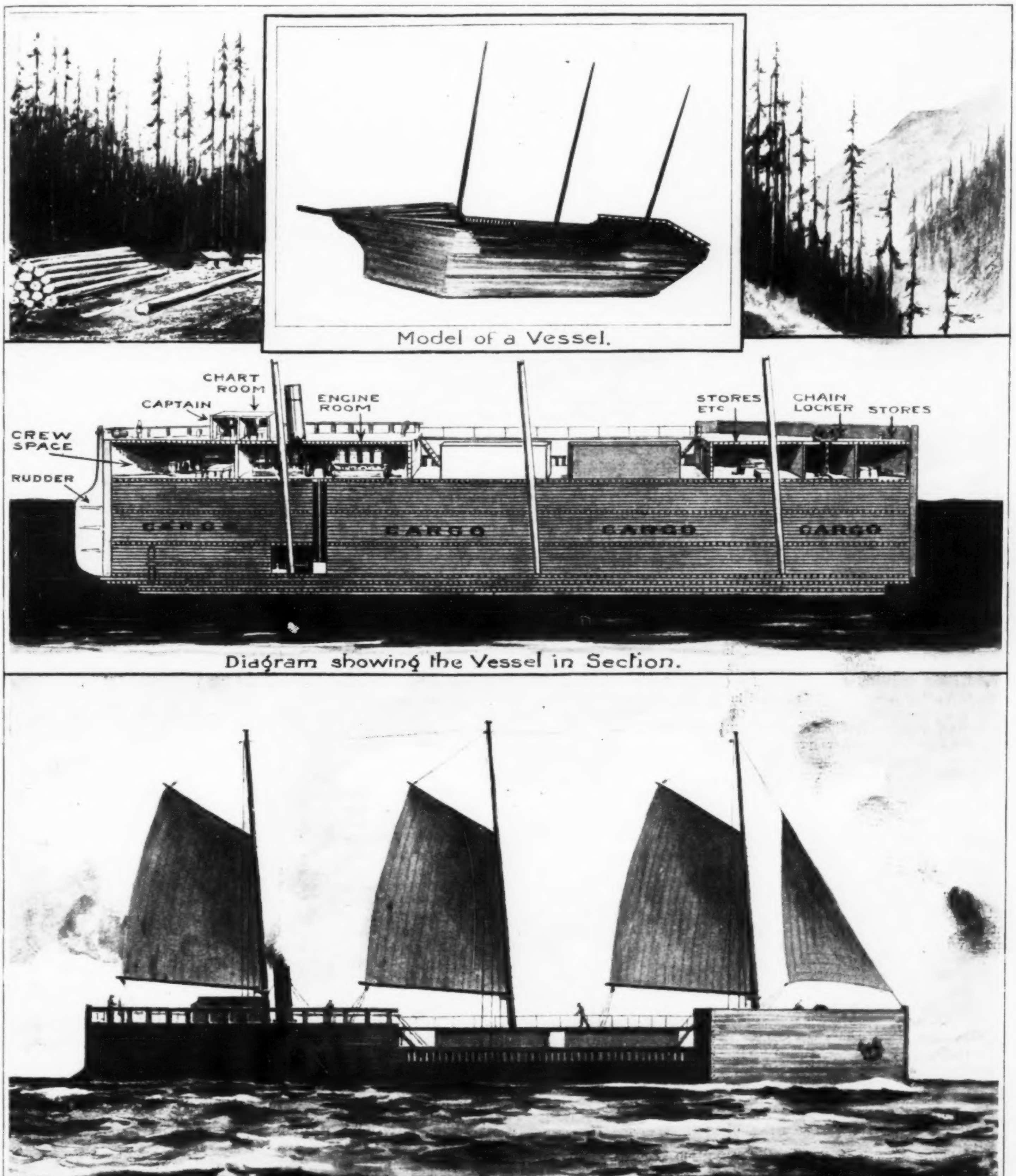


Model of a Vessel.

Diagram showing the Vessel in Section.

Pictorial Diagram of the Vessel at Sea

A new method of shipping lumber on the Pacific Coast

SHIP AND CARGO IN ONE (See p. 383)

Making the Universal Reagent

The Manufacture of Sulphuric Acid by the Chamber Process

By T. R. Horney

It has been said that the progress of a nation in civilization may be measured by the amount of sulphuric acid which it makes and uses, and whatever the truth of this statement the recent Great War has shown us conclusively that the power of a nation on the field of battle depends in large measure on its ability to produce sulphuric acid in great quantities—both of which statements are simply by way of saying that this acid enters, at some stage, into the manufacture of nearly everything that we use, either in peace or war.

When the great war broke over the world in 1914, sulphuric acid along with nearly everything else, suffered quite a slump in the market. Then as the war went on and the European nations began coming to this country for explosives, in the manufacture of which sulphuric acid is a fundamental necessity, it was discovered that the supply was entirely inadequate to meet this enormously increased demand plus the normal consumption of the country. From a thing in the background not worth considering because it had always been there, "sulphuric" became a common word on the tongue of nearly every chemical manufacturer in the country, from the manager of the smallest fertilizer company to the president of the largest "war baby" explosives concern. There was a great scurrying around to obtain long time contracts for acid, to lease abandoned plants, to increase the production of running plants, and finally when it became apparent that these measures would not be sufficient, to build new plants. At last, when we got into the war on our own account the Government as one of its first war measures began planning the construction of plants capable of turning out a tremendous amount of acid.

It is in order that a general idea may be had of the nature of plant required and the process which must be carried on for the production of this widely used substance, that this article is written.

THE PLANT AND RAW MATERIALS REQUIRED.

The process to be described is what is known as the "chamber process" as distinguished from the newer and decidedly different "contact process" which is used principally for the production of stronger acid than that obtained in the chambers.

A chamber acid plant consists, properly, of three parts, though these might be further divided in a technical discussion. These parts are: The burners, or roasters for the formation of sulphur dioxide (the acrid gas which arises when sulphur is burned in the air); the tower department, consisting of the Glover and Gay-Lussac towers, the function of which will be explained later; and the chambers proper, in which the bulk of the acid is made. These three divisions will be taken up in their proper order and described.

The burners or roasters vary greatly, depending upon the materials from which sulphur is to be obtained. Prior to the war a great deal of the acid manufactured in this country was produced from an iron ore called "iron pyrites." This is a combination of iron and sulphur, containing so much of the latter that it burns readily when heated and once started will continue to burn without the further application of external heat. This fact combined with its cheapness and with the fact that the cinder from a pyrites burner had a certain market value as iron ore, made its use very extensive. When pyrites is handled in pieces varying in size from the bigness of a walnut to that of a man's fist, it is called "lump" pyrites, and the burner required is very simple being somewhat similar to an ordinary coal firebox with grates which may be shaken. However, when it is handled in smaller pieces from the size of a pea down to dust, a more elaborate arrangement known as a "fines" burner is required. There are two such burners in general use but space prevents a description of them further than to say that both are based on the principle of spreading the ore in thin layers on a succession of shelves and stirring it by mechanical means.

When the demand for vessels became acute and the lists of embargoed articles were promulgated, it became practically impossible to import pyrites, and as the best of this ore obtainable up to that time had come from Spain, acid manufacturers were forced to turn to domestic materials, and since the deposits of American pyrites had never been extensively developed that meant turning to native sulphur. This substance is found in very large quantities in the Gulf region of Louisiana and Texas and during the past three years great strides have been made in increasing production.

In order to operate on sulphur instead of pyrites certain changes in burners were required. Some companies installed specially designed, mechanically operated sulphur burners in place of their pyrite burners, others merely made a few changes in the pyrites burners and used them for sulphur. Now as anyone who has ever fumigated a house knows, the burning of sulphur is a very simple matter. All you have to do is to set fire to it. It is not quite so simple, however, to burn it properly for the manufacture of acid. The great difficulty experienced with many of the early sulphur burners, particularly when they were not designed by a chemical engineer was "sublimation." This means that a part of the sulphur was vaporized (which is to say, simply evaporated like water in a boiler) instead of being burned to sulphur dioxide as is necessary. This condition is somewhat analogous to a coal fired furnace in which the amount of carbon monoxide in the stack gases is too great, and it is due to exactly the same thing, that is, lack of sufficient air. When it was discovered that the condition could be corrected by the addition of a "combustion chamber" (which is a brick chamber into which the gases from the burner pass and which is provided with air ports to be opened or closed at will) it came to be said among acid makers that "any kind of a thing will burn sulphur if you hook it onto a good combustion chamber," which is probably not true but is close enough for practical purposes.

There are a few other materials besides sulphur and pyrites used in the manufacture of sulphuric acid but their use is not sufficiently extensive to warrant any lengthy discussion in a brief article. Chief among them might be mentioned "zinc blende," a zinc ore containing sulphur, and which must be put through a roasting process for the removal of the sulphur and the substitution of oxygen to render it fit for smelting for the production of metallic zinc. Upon the necessity for this roasting depends its use in the manufacture of acid since the difficulty of roasting it and the elaborate machinery required, as well as the cost of fuel for the application of external heat, which is necessary, make the process too expensive to be carried out for acid making only. Several large plants in the United States operate on this ore, most of them, however, supplementing it during the war by burning native sulphur.

The largest plant in the country operates on the gases obtained from copper furnaces in the smelting of copper ores.

The Nitre Oven.—Older plants have, usually as a part of the burner, a nitre oven. This customarily consists of a small brick chamber through which the sulphur gases pass and which contains a cast iron pot, known as a "nitre pot" or "nitre pig," placed in such a position that the hot gases pass over it. Into this pot at intervals, usually of half an hour, there is put a small amount of nitrate of soda, or as it is frequently called "nitre salt," and a little sulphuric acid. The function of this mixture will be explained later. Many of the newer plants do away with this arrangement and in its stead use nitric acid, which will also be explained later. At the large plant mentioned above a very ingenious system has been devised which would seem to have many of the merits of both methods, without some of their faults.

The Glover Tower.—This is next in order in the plant. The tower is usually constructed about as follows: A structural steel frame, from twenty to fifty feet high and from ten to twenty-five feet square, depending on the size of the plant, is lined with sheets of lead, "burned" or melted together so as to make a tight seam. Inside this lead "curtain" is a wall of brick which may be laid up loose or in some kind of acid-proof mortar, and inside this wall and filling all the rest of the space in the tower is the "packing."

This packing usually consists of acid proof brick laid up in "checker-work" or "honey-comb" fashion which permits of the free upward passage of the gases and the downward flow of the acid which is constantly fed in at the top of the tower during operation.

The top of the tower is burned to the curtains but the bottom or "pan" is constructed separately and is made a little larger than the cross sectional area enclosed by the curtans so that the latter may extend below the top of the pan, well into the acid which it always contains. This prevents the entrance of air or the escape of gas but in no way interferes with the flow of acid out of the pan. An arrangement of this kind is called "luting" and is a device very frequently employed in acid plants.

Above the Glover tower is a piece of apparatus made of lead and called a "*distributor*." The function of this as its name indicates, is to distribute the acid which flows over the tower so that it will be spread evenly over the entire packed area. At the bottom the acid flows out of the pan into "coolers," which are small lead tanks containing coils of lead pipe through which a stream of water is circulated for the purpose of cooling the acid which through its contact with hot gases in the tower acquires a considerable degree of heat.

The *exhauster* is usually placed directly after the Glover tower. This is a large centrifugal fan made of "hard" lead (lead containing a small percentage of antimony which increases its strength) and is for the purpose of maintaining the gas flow throughout the chamber set from the burners to the exit. Old time plants used to run on natural draft but it is customary in modern sets not to depend on such a slow method of circulation.

The Acid Chambers.—On leaving the exhauster we come to the chambers themselves. These are huge lead-walled rooms, the lead being burned together as in the tower, making the chambers gas and liquid proof. The tops are burned to the curtains (sides) and in some plants the pans are also so constructed. In others, however, they are arranged as in the Glover tower, that is, luted.

Chambers vary so greatly in size that it is extremely difficult to make an estimate which will not lay the writer open to criticism by some acid man whose plant happens to come over or under the limits set. It is probable that the average width is somewhere between 22 and 30 feet, and the average height about the same. In length they range from 30 to more than 200 feet. These figures take no account of the particular type of chamber-construction known as "high chambers" in which the height is the greatest dimension. In one plant of this type in the United States there are chambers reaching 77 feet in height, but the type is not common.

Chambers vary almost as widely in number per set as in size, but the average range is between three and ten, though there may be more.

The Gay-Lussac Tower.—The last thing in the chamber system is the Gay-Lussac tower. This is a tower very similar in construction to the Glover tower, but frequently higher and less in cross-sectional area. In the past it has been most frequently packed with coke but the use of other acid resisting materials such as special brick and tile is becoming more common. It has the same type of distributor at the top as is used on the Glover tower but has no coolers at the bottom. Some plants, particularly those operating on other materials than pyrites or native sulphur, employ two or more Gay-Lussac towers in series.

All of these integral parts of the chamber set are connected by flues constructed of lead so that a gas generated in or drawn into the burner must pass through the entire set before it can escape.

Pumping Apparatus.—Another part of the plant, which might almost be considered a separate division, is the pumping apparatus. This may consist, and does in a large majority of the plants of the country, of "eggs" or "blow-cases" by means of which the acid is moved from place to place by the agency of compressed air. These eggs are frequently supplemented by an air-lift (operating on the same principle as those used for water in wells, but constructed of lead) for the purpose of handling the acid directly from the chambers. In some plants the eggs have been entirely replaced by centrifugal pumps of various kinds. Both methods of acid handling have their merits.

OPERATION.

In general there may be said to be two types of chemical process, with reference to continuity. The more common variety is the intermittent or batch type while the other kind of which sulphuric acid manufacture is probably the best known example is the continuous type. This means that once the fires are started in the burners the process goes on indefinitely, day and night, until it is necessary to shut down for repairs or for some other outside reason. It should be borne in mind that while various parts of the process may be referred to as steps, they are all taking place simultaneously in their proper places in the plant.

The first step in the manufacture is the production of sulphur dioxide which takes place in the burners and combustion chambers. By the action of the exhauster this gas is then drawn over the nitre pig, if that method of introducing the necessary oxides of nitrogen be employed, where it is mixed with these oxides. If nitric acid be employed, instead of nitrate of soda and sulphuric acid, a mixture which generates the nitrogen oxides desired, then these gases are obtained when the hot gases from the burner reach the Glover tower where they meet a small stream of nitric acid trickling over the packing of the tower. The heat of the burner gases decomposes the nitric acid setting free the same gases generated by the sulphuric acid and nitrate of soda.

The whole chamber operation depends upon the presence of these nitrogen oxides, but any discussion of the mechanism of the reactions which take place is entirely outside the scope of this article. It is sufficient to say that a certain oxide of nitrogen, called "nitrogen peroxide," seems to have the property of reacting with sulphur dioxide and water to form sulphuric acid. This robs the nitrogen of a part of its oxygen, leaving another oxide of nitrogen, called "nitric oxide," which has the peculiar property of being able to take up oxygen from air, to regenerate the first "nitrogen peroxide." It will thus be seen that so long as a certain amount of air is maintained in the chambers this process may go on and on an indefinite number of times. The success of chamber operation depends to a large extent upon the rapidity with which this cycle takes place.

After being mixed with these nitrogen oxides the sulphur dioxide, together with a certain amount of excess air which has been drawn through the burner and combustion chamber ports, enters the Glover tower at the bottom and passes upward, meeting a mixture of acids from the top of the tower. This acid mixture consists of: acid direct from the chambers, commonly known as "chamber acid;" acid containing more oxides of nitrogen, from the Gay-Lussac tower; a small amount of nitric acid, if that method of introducing nitrogen compounds be employed; and in some cases, when production is being forced so that the burner gases are very hot, a small amount of water. When the sulphur dioxide meets this acid stream the following actions take place: The Gay-Lussac acid, or "nitrous vitriol," is "denitrated," that is, the nitrogen oxides are driven off and pass on into the chambers along with the burner gases; the chamber acid is "concentrated," that is, a part of the water which it contains is evaporated leaving the acid stronger than when it was drawn from the chambers; and the reaction described above, between oxides of nitrogen, water, and sulphur dioxide, takes place to a certain extent, forming some sulphuric acid in the tower instead of waiting until the sulphur dioxide reaches the chambers.

On leaving the tower the remaining gases pass through the exhauster into the first chamber. Here they meet a very finely divided water spray (or, in some plants, jets of steam) furnished by sprays set in the chamber top. When this water meets the gases, the action mentioned above immediately begins to take place and the resulting acid drops to the bottom of the chamber or collects on the curtains. It is usually allowed to collect to a depth of 5 or 6 inches in the pan (sometimes much more in plants which are obliged to use their chambers for storage) and then drawn off to be sent over the Glover tower or used for some purpose for which chamber acid is suitable without further concentration.

After the gases have traversed the first chamber they pass through the connecting flues into the second, and so on throughout the entire set, the action being identical in each except that there is a gradual lessening in intensity in each chamber, due to the progressing consumption of the sulphur dioxide. Finally, when the last chamber has been passed practically all this gas has been used up and the mixture which goes into the Gay-Lussac tower consists of a certain amount of oxygen from the excess air always present when chamber operation is proceeding satisfactorily, a considerable amount of nitrogen which remains from the air used in the chamber process, a very small amount of sulphur dioxide, and the nitrogen oxides. The purpose of the Gay-Lussac tower is the recovery of those oxides, as they are quite expensive. This is accomplished by causing the spent gases to pass upward through the tower against a down-flowing stream of comparatively strong sulphuric acid, in which the oxides are double. This acid is then pumped to the top of the Glover tower, in which it is denitrated as explained above, and the nitrogen oxides set to work again. Unfortunately not all of them can be recovered so that it is necessary that a small amount be continually added at the start of the process.

PLANT CONTROL.

In former days when acid and the materials entering into its manufacture were cheap, not a great deal of attention was paid to the scientific control of chamber sets. The principal method used in controlling the operation, and in some plants probably the only one, was based on the fact stated above, that the intensity of action decreased as the gases approached the last chamber. It was early observed that if the difference in temperature between the first and last chamber, and the difference in the strength of the acid being formed in these chambers were watched and controlled it was very possible to maintain a fairly satisfactory operation. These are still considered very valuable if not necessary records to keep, but the intensive working which has been practiced in the last few years in many American plants has shown the advisability of maintaining a somewhat more elaborate chemical control. In considering the success of chamber plant operation there are four main items to be examined. These are: quantity of acid produced; per cent. of sulphur burned, recovered in the form of sulphuric acid; amount of nitrate of soda used; and wear and tear on the plant. These are not necessarily stated in their order of importance as that order varies with the market price of acid and materials. Any lengthy discussion of these four items would necessarily be of too technical a nature for an article of this kind, so only the first will be treated, as it is probably of more general interest than the others. When "satisfactory" chamber operation is mentioned, it will be understood that all four considerations have been met with reference to the markets at the time of such operation.

In speaking of chamber performance the expression "cubic feet of space" is frequently used. This means the number of cubic feet in the chambers per pound of sulphur, from any source, burned in twenty-four hours. For example, if a plant contain 100,000 cubic feet of space inside the chambers and burn 10,000 pounds of sulphur in twenty-four hours, it is said to be "operating on 10 cubic feet." In the old days, with the ordinary chamber set, if they ran on 14 or 15 cubic feet one thought he was doing very well. Under modern intensive methods the ordinary chamber set may be run successfully on 9 feet, and the superintendent who did not operate on 10 feet at most, during the war rush, did not get the best out of his plant; provided of course that his plant was in reasonably good order, and that in case he was operating on an ore of some kind, it was possible for him to obtain native sulphur to supplement the gases from this ore. It might be said in passing that to the writer's certain knowledge there is one special type of chamber set which will operate successfully on 7 cubic feet, or if given the proper supervision, even on 6. Of course, with such forced conditions, whether on the ordinary or special type set, it is very desirable that the operation be controlled scientifically through the analysis of gases at entrance and exit, of acid from the Gay-Lussac and Glover towers and at less frequent intervals from the chambers, and in certain cases, of gases at different points throughout the system. Old acid makers may scoff at this "chemical control" and it is doubtless true that they can make acid very well without any such observations, but they should bear in mind that during the past three years men of their skill and experience have been exceedingly hard to get and it has been amply demonstrated that a man of much less actual experience may run a plant with entire success if he be guided by good chemical control.

Influence of the Magnetic Field on the Initial Phase of the Electric Discharge

There are a large number of phenomena which can be explained and which may often be foretold by the study of the action of the magnetic field upon the movements of ions and electrons. Research in this line has furnished new confirmations of the theories evolved by physicists in recent years concerning ionization and atomic structure. Interesting examples of such investigations are those conducted by M. Auguste Righi concerning *magnetic rays, iono-magnetic rotations* and the action of the magnetic field upon the electrolitic ions.

It often happens that the ions are animated not only by the thermic movements proper to them, but also by movements due to the existence of a discharge. And we must regard in the same way the modifications which the discharge itself undergoes under the influence of a magnetic field. Among these modifications those which relate to the initial phase of the discharge are of peculiar interest. They have recently been described in the *Annales de Physique* by M. Righi, who has studied them extensively. As we know, it is necessary to establish a certain difference of potential between the electrodes in order to procure the discharge.

The results obtained have been exhibited by the tracing of *characteristic curves* having for their abscissae the intensities given to the field and for their ordinates the corresponding potentials of discharge. In the majority of cases these curves follow a descending path, starting from the axis of the potentials (in other words the potential of discharge begins to diminish under the action of a field of increasing intensity); they pass through a minimum which is often followed by a maximum in the case of very intense fields.

The experimental method followed in making the measurements is theoretically very simple. It is possible either (1) to give a certain intensity to the magnetic field and augment the difference of potential progressively up to the limits of the discharger (inserted in a tube) until the discharge is produced; in order to do which the number of accumulators which serve to establish the difference of potential is increased each time by a single unit; or (2) to apply to the electrodes a definite difference of potential and then to augment the magnetic field slowly by means of a rheostat until the discharge is obtained; there are usually two or three different values of the field corresponding to a single value of the potential of discharge, whence the necessity of employing certain devices because of the well-known fact that the establishment of discharge even for a few moments leaves the gas ionized and because the potential of discharge seems to be diminished if we proceed to a new measurement.

Without dwelling further on the technique of the experiments let us now give some idea of the theory regarding the phenomena observed.

The hypothesis of magneto-ionization propounded by M. Righi defines a new action of the magnetic field. According to this hypothesis every time that the orbit of an atomic electron has an orientation such that the force due to the field is directed outwards as respects the atom, the energy required to separate the electron and thus ionize the atom becomes less—thus the ionization is facilitated. Thus the hypothesis indicates not a new cause of ionization, but a condition tending to favor ionization by shock.

But as thus set forth the hypothesis is open to an objection: the fact is that there are orbits which will be oriented in the direction opposite to the one just considered, and it may be asked whether these effects may not compensate each other. M. Righi shows that this objection can be eliminated by considering the action of the field upon the atoms and the molecules of the gas, i. e. by taking into account the magnetization.

According to the view generally accepted to-day each atom contains a certain number of electrons which describe closed orbits around a central nucleus whose resulting charge is positive. In order to form an idea of the action exerted by the field upon the atoms, we may imagine each orbit of an electron replaced by an electric current of the same form (the direction of the current is opposite to that of the movement of the electron). If the atom had only a single satellite electron the orientation which the field tends to impart would be such that the orbit would have its plane perpendicular to the field and would be traversed by the electron in the direction opposite to that of the closed current to which the field may be attributed. It is probable, moreover, that, in general, each atom possessing several satellite electrons whose orbits are variously oriented, the orienting force would be merely a resultant which might even be nil in particular cases or at certain moments. The action of the field consists, therefore, in a continual tendency of the molecules to orient themselves in a manner similar to that in which molecules of iron orient themselves in a bar of the said metal.

Let us next suppose that the orbit of an electron forming part of an atom has taken the orientation imparted by the field, and assume, for the sake of simplifying the matter, that the said orbit is circular. If we take into account the direction in which the motion of the electron takes place we recognize that the force due to the action of the field upon the electron is directed along the radius of the orbit and towards the exterior. It diminishes the total force which keeps the electron in its orbit, and the energy required to drive the electron away also becomes less. Hence, even if we do not admit the possibility of ionization being produced directly by the magnetic field, it is evident from what has been said above that ionization by shock is facilitated by magnetization.

This conclusion retains its validity even in case the orbits of the satellite electrons of an atom do not attain the orientation imparted by the field, and holds good also for the ensemble of the atoms which compose the gas.

(*Concluded on p. 384*)

The Abrasion-Meter

A Device for Determining the Cutting Efficiency of Abrasive Wheels

By Raymond Francis Yates

It is difficult to overestimate the importance of the modern abrasive wheel in the industry of today. Electrothermic abrasives with their unprecedented hardness, extreme sharpness and fast cutting power have made the grinding wheel an absolutely indispensable article in the industrial world.

Since the advent of the modern abrasive wheel and its important relationship to industry, the value of a machine that could be used in determining the true cutting efficiency of wheels has been recognized. Such a machine would enable manufacturers to conduct tests which would give them valuable data in regard to the nature of the wheels and their efficiency when grinding various substances. Such a machine would be of great benefit to the mechanical world at large, owing to the fact that it would equip manufacturers with a device which would give reliable results to guide them in purchasing those wheels best adapted for specific purposes.

The author recently devised and constructed an abrasive testing machine in the laboratories of the American Society of Experimental Engineers and by the use of this machine some very interesting data was obtained with grinding wheels of various grits, grades and bonds. It was not only possible to plot interesting curves with the device, but a reliable formula was devised by means of which the abrasive efficiency of various wheels may be stated in actual figures. If a workman is able to grind a greater number of brass castings on a certain wheel in one day than on another wheel of a different grade, the manufacturer, of course, decides in favor of the wheel which produces the most work. This is a practical test and we must grant that the manufacturer is right in choosing the wheel which performs the most work, but, on the other hand, it must be admitted that this is by no means a scientific test that will give absolutely reliable results. The value of a machine which would give results in actual figures can be appreciated.

Before describing the machine originated and constructed by the writer, a few words will be said regarding the general nature of abrasive wheels and their manufacture.

Wheels are manufactured with various grits, grades and bonds. The "grit" of a wheel is the size of the abrasive particles which go to make it up. If a wheel is 80 grit, 80 signifies that the abrasive particles which make up the wheel are just able to pass through a screen having 80 meshes to the square inch. A wheel in 20 grit for instance, would be a very coarse wheel and a wheel of 200 grit would be very fine.

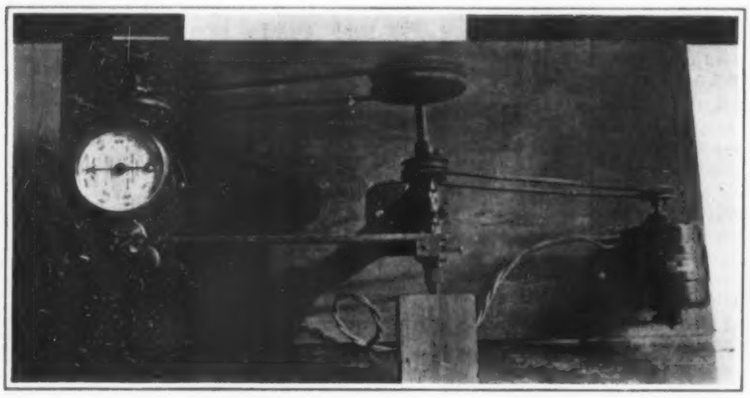
By "grade" is meant the temper or degree of hardness of the abrasive used. The electrothermic processes for the production of modern abrasive substances such as Alundum, Carborundum, Aloxite and Crystalion are under such perfect control that grades of varying hardness can be produced. The grades are indicated by letters and each manufacturer of abrasive wheels has a certain number of letters which cover his different grades running from extremely hard to soft.

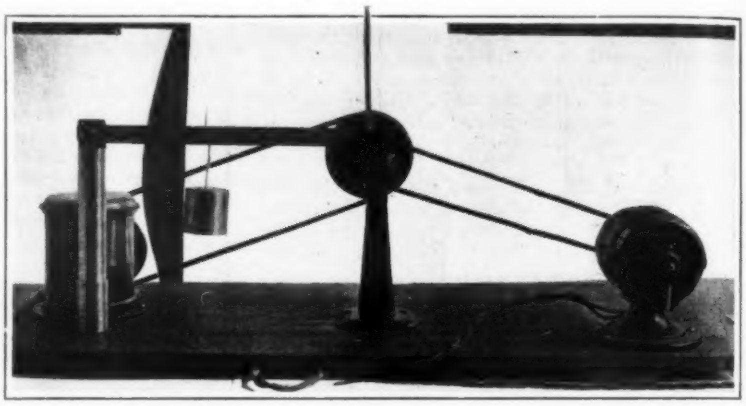
The "bond" of a wheel is the substance that binds the abrasive particles into a solid mass. Various bonding substances are used. Certain fusible vitrifying clays are used. These clays are mixed with abrasive particles, pressed into shape under hydraulic pressure and pl... a vitrifying kiln where fusion of the clays ..., resulting in a hard matrix which holds the ...rticles in place. Vitrified wheels are widely used for various purposes. Silicate wheels are bonded by silicate of soda which has a viscid, tacky nature and which, when dehydrated, forms a solid mass. The abrasive particles are mixed with the silicate of soda and after being shaped are placed in a baking oven where dehydration takes place. Other bonds are used such as shellac and rubber but their use in the industrial field is limited to very special processes and for this reason they will not be considered.

The bond of an abrasive wheel is an extremely important consideration and its nature either contributes or detracts from the efficiency of the wheel. If the bond is too hard for the work that the wheel is doing the abrasive particles cannot break away from their setting rapidly enough and they therefore remain in place until they become very dull. On the other hand, if the bond is too soft the particles lose their connection with the wheel and fall off before their sharpness has disappeared. In the first case, great friction will be developed and the cutting efficiency of the wheel will be considerably reduced. In the second case, the wheel will cut freely and easily but will wear away very rapidly.

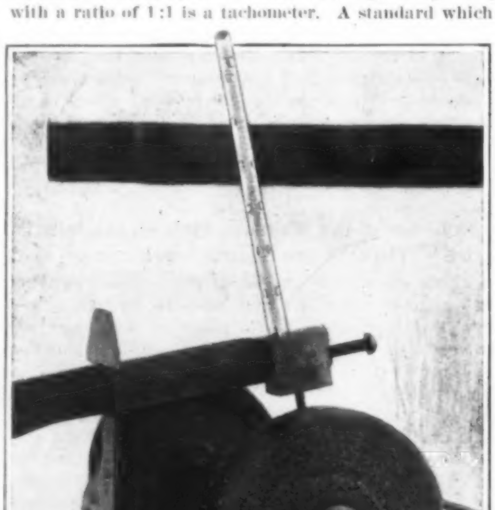
The machine constructed by the author for the determination of abrasive efficiency is shown in the photographs. By the use of this machine, all the figures necessary to calculate the abrasive efficiency are made available. The machine is very simple, and although it was not in accordance with the author's idea of a perfect device, it at least served the purpose of proving that it would be a useful article and that it could be relied upon for results.

A small grinding head is used to mount the wheel upon and this is driven by a small power motor. A rheostat is used in connection with this machine for obtaining various speeds. Belted to the grinding head, with a ratio of 1:1 is a tachometer. A standard which acts as the fulcrum of a lever whose opposite end rests upon the abrasive wheel under test, is mounted at one end of the base. Fixed to the free end of the lever is a small copper block through which a ¼-inch hole is drilled. At the side of this hole another hole is drilled so that it will break into the first hole. The second hole is drilled with a No. 14 drill and the drill is withdrawn just before it breaks through at the bottom. At right angles to the first hole another but longitudinal hole is drilled with a No. 28 drill. This is tapped out with an 8-32 tap to accommodate a set screw which holds the small cylindrical test piece (⅛ in. diam. × 1 in. long) in place. The large hole is used to accommodate the cylindrical bulb of a thermometer so that any rise in temperature of the test piece will be conducted to the bulb of the thermometer and indicated in degrees on the scale. To make the thermal connection between the thermometer and the test piece more perfect mercury is poured into the hole before the thermometer is put in place. A one-pound weight is suspended from the lever by a hook which seats in notches filed at every ½ inch along the top of the lever so that the weight can be adjusted and therefore the pressure upon the wheel can be regulated. The close-up photograph will reveal the details of the device.





Vertical and side views of the Yates Abrasion-Meter



Detail of the Yates Abrasion-Meter

The following factors can be determined by the use of the machine described:

(1) Temperature in degrees Centigrade.
(2) Amount of metal removed from the test piece.
(3) Surface velocity of the wheel in feet.
(4) Pressure or load on the wheel in pounds.
(5) Time in minutes.

The following formula is used in determining the efficiency of the wheel:

$$\text{Efficiency} = 1 \div t\,l\,v\,p\;T,$$

Where:

t = temperature,
l = metal removed,
v = surface velocity,
p = pressure or load,
T = time.

Some curves were plotted by the use of this machine which showed the relation between temperature and time with steel stock at given pressures and speeds with different grades of wheels. An interesting curve in this respect was plotted for conditions when the speed was 600 R.P.M., which gives a surface velocity of 4471 ft. per minute. The wheel used was Carborundum 3 in. in diameter and 80 grit, and the load was 3.5 pounds. The rise in temperature was fairly rapid until 31 degrees C. was approached. At this point the curve rounded out.

A somewhat interesting result shown in Fig. 1 was obtained with the same wheel by increasing the speed of the motor to 1,000 R.P.M. and reducing the load to 1.5 lbs. The time element was also extended to 3 minutes. The temperature mounted rapidly until it reached 34 degrees C. At this point, the curve flattened out. Although the temperature mounted more quickly in this test than it did in the previous one, over four times as much metal was removed from the test piece.

It is well to mention at this point that the temperature is a factor that is generally controlled by friction. If the abrasive particles of the wheel do not break away from their setting after losing their sharpness the wheel rubs the surfaces of the metal without cut-

ting and this produces friction. Friction is always attended by a rise in temperature. In the average case, the temperature for a given time can be taken as some indication of the cutting efficiency of an abrasive wheel. The curve in Fig. 2 is an interesting one and it shows how excessive speed of a wheel will reduce its cutting power. The wheel used was a Carborundum, grade J, grit 60 and had a diameter of 3 inches. The test was started at 100 R.P.M. and the speed gradually increased to 1,700. Up to 1,300 R.P.M. the rise in temperature was gradual but at this point it mounted suddenly to 38 deg. The test showed that the most efficient cutting speed for this wheel when used with this particular stock was in the neighborhood of 1,300 R.P.M.

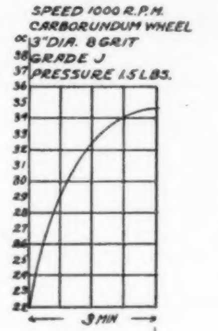


Fig. 1

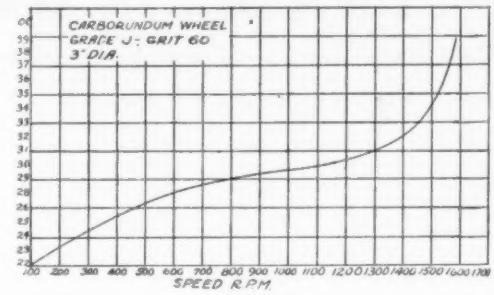


Fig. 2

Fig. 3 shows the results obtained with an Aloxite wheel of 180 grit. The pressure was 1.5 pounds and the speed 600 R.P.M. In this test the temperature mounted somewhat abruptly to 440 deg. in 3 minutes. The result of this test proved beyond question that this wheel had a particularly low cutting efficiency when used in connection with stock of the nature of that

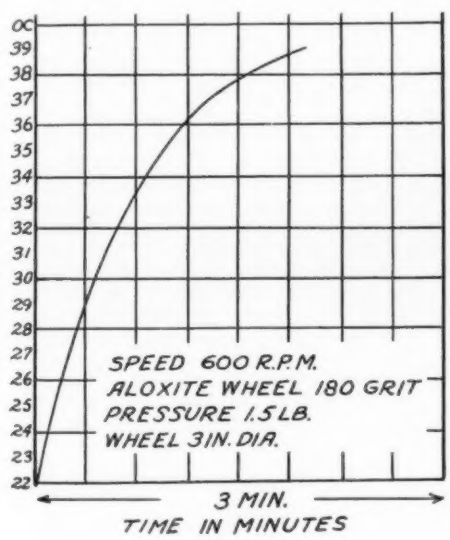


Fig. 3

which constituted the test piece. The low efficiency was probably caused by the fine grit of the abrasive wheel which was used.

An interesting test was made with a 3-inch Carborundum wheel 80 grit, grade J. The result of this test is shown in Fig. 4, and it will be noticed that the speed was 600 R.P.M. and the pressure 1.5 lbs. The test piece was steel stock and the temperature took a very normal rise to 35 deg. in 3 minutes. Other inter-

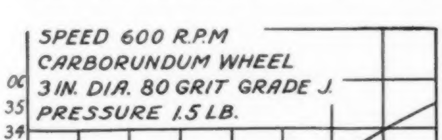


Fig. 4

esting charts could be plotted which would show the relationship between temperature and pressure as well as speed and temperature at constant pressures; also the relationship between the amount of metal removed and the temperature.

The few tests conducted by the author were by no means exhaustive and it is hoped that those who are interested in the subject will carry the work of perfection and investigation further, using the data set forth in this treatment as a guide. The author believes in the promising possibility of developing his device into a reliable testing machine to determine the abrasve efficiency of wheels when used to grind various substances.

Measurement of Heat Losses Through Insulating Materials

The author points out that progress in the preparation of non-conducting materials depends upon the existence of reliable data, and indicates the best methods of obtaining same.

Rough comparisons are misleading because they do not distinguish between losses due to conductivity, convection, and radiation. The latter should not be neglected. Tests carried out on asbestos insulation in technical institutions have been examined and found of little practical value as they only refer to comparative conductivity of different materials.

Tests with continuous heat currents have been carried out according to the methods proposed by Nusselt, Gröber, Poensgen and van Rinsum. They all employ heat produced and measured electrically for determining the quantities of heat passing through test-pieces which are classified according to shape, such as hollow spheres, hollow cylinders, etc., and plates.

Nusselt uses hollow test-pieces with internal electric heating coils. The heat-loss-coefficients for various temperatures can thus be determined from one experiment. He has worked out the analogy between the lines of the heat current and the lines of force for the electric current, and made the method applicable to all hollow vessels. The measurements range from 59° F. to 1,040° F. Gröber has extended the measurements for refrigerating practise to –288° F., and van Rinsum has tested firebricks up to 1,832° F.

The heat-loss-coefficients for the whole series from 288° F. to 1,832° F. showed an increase proportionate to the temperature. The experiments with high temperatures made by van Rinsum are the most reliable, but they apply to specially made segments only.

The conductivity of hollow cylinders for protecting steam pipes was determined. Test cylinders were made of such a length that the axial losses were comparatively small. He was the first to develop a formula for the heat-loss-coefficients in which this source of inaccuracy is allowed for.

Gröber tested two similar plates with an electric heater inserted between them. Heat losses at the edges of the plates are prevented by means of Poensgen's electrically heated protecting rings, but the losses in testing good non-conductors due to the width of the slit used by Poensgen is considerable, and a narrower slit should be substituted.

Tests were carried out in the Government Testing Station at Charlottenburg according to Gröber's method, but protecting rings were not used, and the heat losses were allowed for in a formula which is identical with van Rinsum's for hollow cylinders.

The author shows how the two-plate and the hollow cylinder methods can be made applicable to very high temperatures as required for experiments with firebricks instead of calorimeters formerly used. Goerens has improved the experiment by introducing electric heaters, thermo-piles built into the material, and a protecting ring whereby the flow of heat is directed to the test-plate.—*Zeitschrift des Vereines Deutscher Ingenieure.*

Celebes Ore Deposits

A chemical analysis shows that the Celebes iron-ores are equal in value to those of New Caledonia and the Philippines, and superior to those of Cuba. It is estimated that at least 1 milliard tons of ore are contained in the island. Experts consider that the electro-metallurgic process is the most suitable for the manufacture of the Celebes ores, and about 300,000 h.p. from the water-power of the Matili River is available for generating the necessary current. It would be possible to produce 500,000 t. of pig-iron or of steel annually from about 1 mill. t. of ore, but it would be necessary to convey 170,000 t. of coal up to the works. It will probably be found expedient to construct a cable railway for this purpose, and the cost of the steel works, railway, harbor works, and power-station is estimated at Fl.125 mill.

Dr. Heber concludes his article by a detailed account of the nickel ore deposits in the island. Between 1825 and 1915 the amount of nickel used in industries increased from 2,500 to 175,000 tons.—*Wirtschaftsdienst.*

A New Dew-Gage (Drosometer)*

Professor Eredia of the Central Meteorological Bureau at Rome has devised a new drosometer which he describes in *L'Agricoltura Coloniale.*

The device consists essentially of a hemispherical Dewar cup having its double walls silvered, and with an interior area of 100 sq. cm. (*C* in Fig. 1). The deposit of dew is measured in this cup. To prevent evaporation or an unforeseen rain from invalidating the results, in case measurement cannot be made at once, the cup is fixed in a wooden box in such a manner that the rim of the cup is flush with the box cover which has cut in it a circular opening precisely equal to the area of the circular aperture of the cup, and which may be closed automatically.

The closing device, which, by the way is applicable to many other instruments, consists of a clock-movement *H*, placed within the box, and may be a simple alarm clock whose gong and hammer have been removed and replaced by a rod, *t*, fixed to the spring of the alarm. This rod is hinged at its upper end, to a lever whose fixed end is at *l*, and whose free end carries a pin, *b*, which acts as a stop to the movable circular cover. This cover is attached to a spring, *r*, which tends to turn it about the pivot *p* as soon as the stop no longer opposes its resistance.

The clock-work is wound up, the alarm release is set to go off precisely at sunrise; the movable lid is opened and remains "set" with its spring tense, against the stop. Thus prepared the apparatus is placed on

Eredia's Drosometer or Dew Measurer

the ground at the point where measurements are to be made. The cup remains exposed throughout the night, if the meteorological conditions are favorable dew is formed in the cup, and at dawn the lid hermetically closes the cup preventing all evaporation.

In order to measure the amount of water condensed one may not pour it out into a graduated measure as this would cause a loss of liquid; to weigh it would consume some little time. Prof. Eredia employs an iron tripod whose extremities are fitted with points that fit on three metallic disks countersunk in the fixed box cover. The center of the tripod, which coincides with the axis of the cup, consists of a screw in which fits a micrometer screw having a milled head, *m*, and terminating in a sharp point at its lower end. To the milled head is attached a divided circle whose edge is against a vertical scale rod, *g*, divided into millimeters. The zero on the scale, *g*, corresponds to the condition when the point of the screw is in contact with the bottom of the cup. This kind of spherometer permits one to read to the 50th and even to the 100th of a millimeter.

To make a reading the screw is turned until its lower point just touches the surface of the water in the bottom of the cup, a position which is easily determined since the point is reflected in the water. When the point and its image are exactly in contact one notes the height of the water on the graduated scale, *g* and on the divided circle. Thus one determines the height, *h*, of a spherical segment of calculable volume. A table prepared in advance eliminates the repetition of this calculation.

*Translated for The Scientific American Supplement from *La Nature* (Paris).

The Color of Water—I*

A Valuable Compendium of the Literature on a Neglected Subject

By Prof. Wilder D. Bancroft, Ph.D., Cornell

The literature on the color of water is widely scattered; it appears not to have been read by anybody; and it is somewhat contradictory. It has, therefore, seemed desirable to collect the material in an accessible form as it constitutes an interesting chapter in the general subject of the colors of colloids.

Tyndall[1] has discussed the blue color of turbid media with special reference to the color of the sky and of the sea. In Newton's rings the color nearest to the central black spot is a faint blue—blue of the first order—corresponding to the film of air when thinnest. "If a solid or liquid, of the thickness requisite to produce this color were broken into bits and scattered in the air, Newton inferred that the tiny fragments would display the blue color. Tantamount to this, he considered, was the addition of minute water-particles in the incipient stage of their condensation from aqueous vapor. Such particles suspended in our atmosphere ought, he supposed, to generate the serenest skies. Newton does not appear to have bestowed much thought upon this subject; for to produce the particular blue which he regarded as sky-blue, thin plates with parallel surfaces would be required. The notion that cloud-particles are hollow spheres, or vesicles, is prevalent on the Continent, but it never made any way among the scientific men of England. De Saussure thought that he had actually seen the cloud-vesicles, and Faraday, as I learned from himself, believed that he had once confirmed the observation of the illustrious Alpine traveler. During my long acquaintance with the atmosphere of the Alps I have often sought for these aqueous bladders, but have never been able to find them. Clausius once published a profound essay on the colors of the sky. The assumption of small water drops, he proved, would lead to optical consequences entirely at variance with facts. For a time, therefore, he closed with the idea of vesicles, and endeavored to deduce from them the blue of the firmament and the morning and evening red.

"It is not, however, necessary to invoke the blue of the first order to explain the color of the sky; nor is it necessary to impose upon condensing vapor the difficult, if not impossible, task of forming bladders, when it passes into the liquid condition. Let us examine the subject. Eau-de-Cologne is prepared by dissolving aromatic gums or resins in alcohol. Dropped into water, the scented liquid immediately produces a white cloudiness, due to the precipitation of the substances previously held in solution. The solid particles are, however, comparatively gross; but, by diminishing the quantity of the dissolved gum, the precipitate may be made to consist of extremely minute particles. Brücke, for example, dissolved gum-mastic, in certain proportions, in alcohol, and carefully dropping his solution into a beaker of water, kept briskly stirred, he was able to reduce the precipitate to an extremely fine state of division. The particles of mastic can by no means be imagined as forming bladders. Still, against a dark ground—black velvet for example—the water that contains them shows a distinctly blue color. The bluish color of many liquids is produced in a similar manner. Thin milk is an example. Blue eyes are also said to be simply turbid media. The rocks over which glaciers pass are finely ground and pulverized by the ice, or the stony emery imbedded in it; and the river which issues from the snout of every glacier is laden with suspended matter. When such glacier water is placed in a tall glass jar, and the heavier particles are permitted to subside, the liquid column, when viewed against a dark background, has a decidedly bluish tinge. The exceptional blueness of the Lake of Geneva, which is fed with glacier water may be due, in part, to particles small enough to remain suspended long after their larger and heavier companions have sunk to the bottom of the lake.

"We need not, however, resort to water for the production of the color. We can liberate, in air, particles of a size capable of producing a blue as deep and pure as the azure of the firmament. In fact, artificial skies may be thus generated, which prove their brotherhood with the natural sky by exhibiting all its phenomena. There are certain chemical compounds—aggregates of molecules—the constituent atoms of which are readily shaken asunder by the impact of special waves of light. Probably, if not certainly, the atoms and the waves are so related to each other, as regards vibrating period, that the wave-motion can accumulate until it becomes disruptive. A great number of substances might be mentioned whose vapors, when mixed with air and subjected to the action of a solar or an electric beam, are thus decomposed, the products of decomposition hanging as liquid or solid particles in the beam which generates them. And here I must appeal to the inner vision already spoken of. Remembering the different sizes of the waves of light, it is not difficult to see that our minute particles are larger with respect to some waves than to others. In the case of water, for example, a pebble will intercept and reflect a larger fractional part of a ripple than of a larger wave. We have now to imagine light-undulations of different dimensions, but all exceedingly minute, passing through air laden with extremely small particles. It is plain that such particles, though scattering portions of all the waves, will exert their most conspicuous action upon the smallest waves—in other words, the color line—will be predominant in the scattered light. This harmonizes perfectly with what we observe in the firmament. The sky is blue, but the blue is not pure. On looking at the sky through a spectroscope, we observe all the colors of the spectrum; blue is merely the predominant color. By means of our artificial skies we can take as it were, the firmament in our hands and examine it at our leisure. Like the natural sky, the artificial one shows all the colors of the spectrum; but blue in excess. Mixing very small quantities of vapor with air, and bringing the decomposing luminous beam into action, we produce particles too small to shed any sensible light, but which may, and doubtless do, exert an action on the ultra-violet waves of the spectrum. We can watch these particles, or rather the space they occupy, till they grow to a size able to yield the firmamental azure. As the particles grow larger under the continued action of the light, the azure becomes less deep; while later on a milkiness, such as we often observe in nature, takes the place of the purer blue. Finally the particles become large enough to reflect all the light-waves, and then the suspended 'actinic cloud' diffuses white light. . . .

"In the harbor of Gibraltar, on the morning of our departure, I resumed a series of observations on the color of the sea. On the way out a number of specimens had been collected, with a view of subsequent examinations. But the bottles were claret bottles, of doubtful purity. At Gibraltar, therefore, I purchased fifteen white glass bottles, with ground-glass stoppers, and at Cadiz, thanks to the friendly guidance of Mr. Cameron, I secured a dozen more. These seven and twenty bottles were filled with water, taken at different places between Oran and Spithead. And here let me express my warmest acknowledgments to Captain Henderson, the commander of H. M. S. Urgent, who aided me in my observations in every possible way. Indeed, my thanks are due to all the officers for their unfailing courtesy and help. The captain placed at my disposal his own coxswain, an intelligent fellow named Thorgood, who skilfully attached a cord to each bottle, weighted it with lead, cast it into the sea, and, after three successive rinsings, filled it under my own eyes. The contact of jugs, buckets, or other vessels was thus avoided; and even the necessity of pouring out the water, afterward, through the dirty London air.

"The mode of examination applied to these bottles has been already described. The liquid is illuminated by a powerfully condensed beam, its condition being revealed through the light scattered by its suspended particles. Care is taken to defend the eye from the access of all other light, and, thus defended, it becomes an organ of inconceivable delicacy. Were water of uniform density perfectly free from suspended matter, it would, in my opinion, scatter no light at all. The track of a luminous beam could not be seen in such water. But an amount of impurity so infinitesimal as to be scarcely expressible in numbers, and the individual particles of which are so small as wholly to elude the microscope, may, when examined by the method alluded to, produce not only sensible, but striking, effects upon the eye.

"The results of the examination of nineteen bottles filled at various places between Gibraltar and Spithead are tabulated in Table I.

"Here we have three specimens of water, described as green, a clearer green and bright green, taken in Gibraltar Harbor, and off Cabreta Point. The home examination showed the first to be thick with suspended matter, the second less thick, and the third still less thick. Thus the green brightened as the suspended matter diminished in amount.

Table I.

No.	Location	Color of Sea	Appearance in Luminous Beam
1	Gibraltar Harbor	Green	Thick with fine particles.
2	Two miles from Gibraltar	Clearer green	Thick with very fine particles
3	Off Cabreta Point	Bright green	Still thick, but less so.
4	Off Cabreta Point	Black-indigo	Much less thick, very pure.
5	Off Tarifa	Undecided	Thicker than No. 4.
6	Beyond Tarifa	Cobalt-blue	Much purer than No. 5.
7	Twelve miles from Cadiz	Yellow-green	Very thick.
8	Cadiz Harbor	Yellow-green	Exceedingly thick.
9	Fourteen miles from Cadiz	Yellow-green	Thick, but less so.
10	Fourteen miles from Cadiz	Bright green	Much less thick.
11	Between Capes St. Mary and Vincent	Deep indigo	Very little matter, very pure.
12	Off the Burlings	Strong green	Thick, with fine matter.
13	Beyond the Burlings	Indigo	Very little matter, pure.
14	Off Cape Finisterre	Undecided	Less pure.
15	Bay of Biscay	Black-indigo	Very little matter, very pure.
16	Bay of Biscay	Indigo	Very fine matter. Iridescent.
17	Off Ushant	Dark green	A good deal of matter.
18	Off St. Catherine's	Yellow-green	Exceedingly thick.
19	Spithead	Green	Exceedingly thick.

"Previous to the fourth observation our excellent navigating lieutenant, Mr. Brown, steered along the coast, thus avoiding the adverse current which sets in, through the Strait, from the Atlantic to the Mediterranean. He was at length forced to cross the boundary of the Atlantic current, which was defined with extraordinary sharpness. On the one side of it the water was a vivid green, on the other a deep blue. Standing at the bow of the ship, a bottle could be filled with blue water, while at the same moment a bottle cast from the stern could be filled with green water. Two bottle were secured, one on each side of this remarkable boundary. In the distance the Atlantic had the hue called ultra-violet; but looked fairly down upon, it was of almost inky blackness—black qualified by a trace of indigo.

"What change does the home examination here reveal? In passing the indigo, the water becomes suddenly augmented in purity, the suspended matter becoming suddenly less. Off Tarifa, the deep indigo disappears, and the sea is undecided in color. Accompanying this change, we have a rise in the quantity of suspended matter. Beyond Tarifa, we change to cobalt-blue, the suspended matter falling at the same time in quantity. This water is distinctly purer than the green. We approach Cadiz, and at twenty miles from the city get into yellow-green water; this the London examination shows to be thick with suspended matter. The same is true at Cadiz Harbor, and also of a point fourteen miles from Cadiz in the homeward direction. Here there is a sudden change from yellow-green to a bright emerald-green, and accompanying the change a sudden fall in the quantity of suspended matter. Between Cape St. Mary and Cape St. Vincent the water changes to the deepest indigo, a further diminution of the suspended matter being the concomitant phenomenon.

"We now reach the remarkable group of rocks called the Burlings, and find water between the shore and the rocks a strong green; the home examination shows it to be thick with fine matter. Fifteen or twenty miles beyond the Burlings we come again into indigo water, from which the suspended matter has in great part disappeared. Off Cape Finisterre, about the place where the Captain went down, the water becomes green, and the home examination pronounces it to be thicker. Then we enter the Bay of Biscay, where the indigo resumes its power, and where the home examination shows the greatly augmented purity of the water. A second specimen of water, taken from the Bay of Biscay, held in suspension fine particles of a peculiar kind; the size of them was such as to render the water richly iridescent. It showed itself green, blue or salmon-colored, according to the direction of the line of vision. Finally, we come to our last two bottles, the one taken opposite St. Catherine's lighthouse, on the Isle of Wight, the other at Spithead. The sea at both these places was green, and both specimens, as might be expected, were pronounced by the home examination to be thick with suspended matter.

"Two distinct series of observations are here referred to—the one consisting of direct observations of the color of the sea, conducted during the voyage from Gibraltar to Portsmouth, the other carried out in the

*Reprinted from *Journal of the Franklin Institute*, Philadelphia.

[1]"Fragments of Science: The Sky; Voyage to Algeria; Niagara."

laboratory of the Royal Institution. And here it is to be noted that in the home examination I never knew what water was placed in my hands. The labels, with the names of the localities written upon them, had been tied up, all information regarding the source of the water being thus held back. The bottles were simply numbered, and not till all of them had been examined, and described, were the labels opened, and the locality and sea-color corresponding to the various specimens ascertained. The home observations, therefore, must have been perfectly unbiased, and they clearly establish the association of the green color with fine suspended matter, and of the ultramarine color, and more especially of the black-indigo hue of the Atlantic, with the comparative absence of such matter.

"So much for mere observation; but what is the cause of the dark hue of the deep ocean? A preliminary remark or two will clear our way toward an explanation. Color resides in white light, appearing when any constituent of the white light is withdrawn. The hue of a purple liquid, for example, is immediately accounted for by its action on a spectrum. It cuts out the yellow and green, and allows the red and blue to pass through. The blending of these two colors produces the purple. But while such a liquid attacks with special energy the yellow and green, it enfeebles the whole spectrum. By increasing the thickness of the stratum we may absorb the whole of the light. The color of a blue liquid is similarly accounted for. It first extinguishes the red; then, as the thickness augments, it attacks the orange, yellow, and green in succession; the blue alone finally remaining. But even it might be extinguished by a sufficient depth of the liquid.

"And now we are prepared for a brief, but tolerably complete, statement of that action of sea-water upon light to which it owes its darkness. The spectrum embraces three classes of rays—the thermal, the visual and the chemical. These divisions overlap each other; the thermal rays are in part visual, the visual rays in part chemical and vice-versa. The vast body of thermal rays lies beyond the red, being invisible. These rays are attacked with exceeding energy by water. They are absorbed close to the surface of the sea, and are the great agents in evaporation. At the same time the whole spectrum suffers enfeeblement; water attacks all its rays, but with different degrees of energy. Of the visual rays, the red are first extinguished. As the solar beam plunges deeper into the sea, orange follows red, yellow follows orange, green follows yellow and the various shades of bue, where the water is deep enough, follow green. Absolute extinction of the solar beam would be the consequence if the water were deep and uniform. If it contained no suspended matter, such water would be as black as ink. A reflected glimmer of ordinary light would reach us from its surface, as it would from the surface of actual ink; but no light, hence no color, would reach us from the body of the water. In very clear and deep sea-water this condition is approximately fulfilled, and hence the extraordinary darkness of such water. The indigo, already referred to, is, I believe, to be ascribed in part to the suspended matter, which is never absent, even in the purest natural water; and in part to the slight reflection of the light from the limiting surfaces of strata of different densities. A modification of light is thus thrown back to the eye, before the depth necessary to absolute extinction has been attained. An effect precisely similar occurs under the moraines of glaciers. The ice here is exceptionally compact, and, owing to the absence of the internal scattering common in bubbled ice, the light plunges into the mass, where it is extinguished, the perfectly clear ice presenting an appearance of pitchy blackness.[2]

"The green color of the sea has now to be accounted for; and here, again, let us fall back upon the sure basis of experiment. A strong white dinner-plate had a lead weight securely fastened to it. Fifty or sixty yards of strong hempen line were attached to the plate. My assistant, Thorgood, occupied a boat, fastened as usual to the davits of the Urgent, while I occupied a second boat nearer the stern of the ship. He cast the plate as a mariner heaves the lead, and by the time it reached me it had sunk a considerable depth in the water. In all cases the hue of this plate was green. Even when the sea was of the darkest indigo, the green was vivid and pronounced. I could notice the gradual deepening of the color as the plate sank, but at its greatest depth, even in indigo water, the color was still green.[3]

"Other observations confirmed this one. The Urgent is a screw steamer, and right over the blades of the screw was an orifice called the screw-well, through which one could look from the poop down upon the screw. The surface-glimmer, which so pesters the eye, was here in a great measure removed. Midway down, a plank crossed the screw-well from side to side; on this I placed myself and observed the action of the screw underneath. The eye was rendered sensitive by the moderation of the light; and, to remove still further all disturbing causes, Lieutenant Walton had a sail and tarpaulin thrown over the mouth of the well. Underneath this I perched myself on the plank and watched the screw. In an indigo sea the play of color was indescribably beautiful, and the contrast between the water, which had the screw blades, and that which had the bottom of the ocean, as a background, was extraordinary. The one was of the most brilliant green, and the other of the deepest ultramarine. The surface of the water above the screw-blade was always ruffled. Liquid lenses were thus formed, by which the light was withdrawn from some places and concentrated upon others, the water flashing with metallic lustre. The screw-blades in this case played the part of the dinner-plate in the former case, and there were other instances of a similar kind. The white bellies of porpoises showed the green hue, varying in intensity as the creatures swung to and fro between the surface and the deeper water. Foam, at a certain depth below the surface, was also green. In a rough sea the light which penetrated the summit of a wave sometimes reached the eye, a beautiful green cap being thus placed upon the wave, even in indigo water.

"But how is this color to be connected with the suspended particles? Take the dinner-plate which showed so brilliant a green when thrown into indigo water. Suppose it to diminish in size, until it reaches an almost microscopic magnitude. It would still behave substantially as the larger plate, sending to the eye its modicum of green light. If the plate, instead of being a large coherent mass, were ground to powder sufficiently fine, and in this condition diffused through the clear sea-water, it would also send green to the eye. In fact, the suspended particles which the home examination reveals act in all essential particulars like the plate, or like the screw-blades, or like the foam, or like the bellies of the porpoises. Thus I think the greenness of the sea is physically connected with the matter which it holds in suspension. . . .

"At some distance below the Whirlpool Rapids we have the celebrated whirlpool itself. Here the river makes a sudden bend to the northeast, forming nearly a right angle with its previous direction. The water strikes the concave bank with great force, and scoops it incessantly away. A vast basin has been thus formed, in which the sweep of the river prolongs itself in gyratory currents. Bodies and trees which have come over the falls are stated to circulate here for days without finding the outlet. From various points of the cliffs above this is curiously hidden. The rush of the river into the whirlpool is obvious enough; and though you can imagine the outlet must be visible if one existed, you cannot find it. Turning, however, round the bend of the precipice to the northeast, the outlet comes to view.

"The Niagara season was over; the chatter of sightseers had ceased, and the scene presented itself as one of holy seclusion and beauty. I went down to the river's edge, where the weird loneliness seemed to increase. The basin is enclosed by high and almost precipitous banks—covered, at the time, with russet woods. A kind of mystery attaches itself to gyrating water, due perhaps to the fact that we are to some extent ignorant of the direction of its force. It is said that, at certain points of the whirlpool, pine-trees are sucked down, to be ejected mysteriously elsewhere. The water is of the brightest emerald-green. The gorge through which it escapes is narrow, and the motion of the river swift though silent. The surface is steeply inclined, but it is perfectly unbroken. There are no lateral waves, no ripples with their breaking bubbles to raise a murmer, while the depth is here too great to allow the inequality of the bed to ruffle the surface. Nothing can be more beautiful than this sloping liquid mirror formed by the Niagara in sliding from the whirlpool.

"The green color is, I think, correctly accounted for in the last Fragment. While crossing the Atlantic, in 1872-1873, I had frequent opportunities of testing the explanation there given. Looked properly down upon, there are portions of the ocean to which we should hardly ascribe a trace of blue; at the most, a mere hint of indigo reaches the eye. The water, indeed, is practically black, and this is an indication both of its depth and of its freedom from mechanically suspended matter. In small thicknesses water is sensibly transparent to all kinds of light; but, as the thickness increases the rays of low refrangibility are first absorbed, and after them the other rays. Where, therefore, the water is very deep and very pure, all the colors are absorbed, and such water ought to appear black, as no light is sent from its interior to the eye. The approximation of the Atlantic Ocean to this condition is an indication of its extreme purity.

"Throw a white pebble into such water; as it sinks it becomes greener and greener, and before it disappears, it reaches a vivid blue-green. Break such a pebble into fragments, each of these will behave like the unbroken mass; grind the pebble to powder, every particle will yield its modicum of green; and if the particles be so fine as to remain suspended in the water, the scattered light will be a uniform green. Hence the greenness of shoal water. You go to bed with the black Atlantic around you. You rise in the morning, find it a vivid green, and correctly infer that you are crossing the bank of Newfoundland. Such water is found charged with fine matter in a state of mechanical suspension. The light from the bottom may sometimes cross into play, but it is not necessary. A storm can render the water muddy, by rendering the particles too numerous and gross. Such a case occurred toward the close of my visit to Niagara. There had been rain and storm in the upper lake-regions, and the quantity of suspended matter brought down quite extinguished the fascinating green of the Horseshoe.

"Nothing can be more superb than the green of the Atlantic waves, when the circumstances are favorable to the exhibition of the color. As long as a wave remains unbroken no color appears; but when the foam just doubles over the crest, like an Alpine snow-cornice, under the cornice we often see a display of the most exquisite green. It is metallic in its brilliancy. But the foam is necessary to its production. The foam is first illuminated, and it scatters the light in all directions; the light which passes through the higher portion of the wave alone reaches the eye, and gives to that portion its matchless color. The folding of the wave, producing as it does a series of longitudinal protuberances and furrows which act like cylindrical lenses, introduces variation in the intensity of the light and materially enhances its beauty."

The question of the color of the Mediterranean and of other waters has been studied with a good deal of care by Aitken, whose work seems not to have received the attention which it deserves. Only a lengthy abstract of his paper is available and I quote from that.[4]

"The experiments were made with a special view of determining whether the selective reflection or the selective absorption theory gave the correct explanation of the blueness seen in water. According to the selective reflection theory the color is due to the light reflected by extremely small particles of matter suspended in the water, these particles being so small they can reflect only the short waves of light, or those which belong to the blue end of the spectrum. The other theory explains the color by supposing that water has a selective absorption for the rays of the red end of the spectrum—that water is in fact a blue transparent medium. Three different methods were adopted of testing the correctness of these rival theories, and all three proved the water of the Mediterranean to be blue by selective absorption, and show that light in passing through the water has the rays of the red end of the spectrum absorbed, and only those of the blue end transmitted. The first method tried was to find out what is the color of the illumination of submerged objects. This was done by taking a long metal tube, closed at the end with a glass plate, sinking it vertically in the water, and looking through it at white and different colored objects fixed near the end of the tube. When this was done, it was found that a white object appeared of a most beautiful deep and delicate blue at a depth of 6 m. If the selective reflection theory was true, submerged objects would be illuminated with a color complementary to that reflected by the fine particles, and would therefore appear orange or yellow, the exact color depending on the amount of green in the reflected blue. If the blue color of the sky, as generally supposed, is due to the reflection of the blue rays by small particles of matter suspended in the air, it obviously follows that light in passing through our atmosphere must become of a color complementary to the blue of the sky; and it is asked, may not this be one of the reasons why the sun near the horizon, and all artificial lights when seen at a great distance, appear more or less yellow?

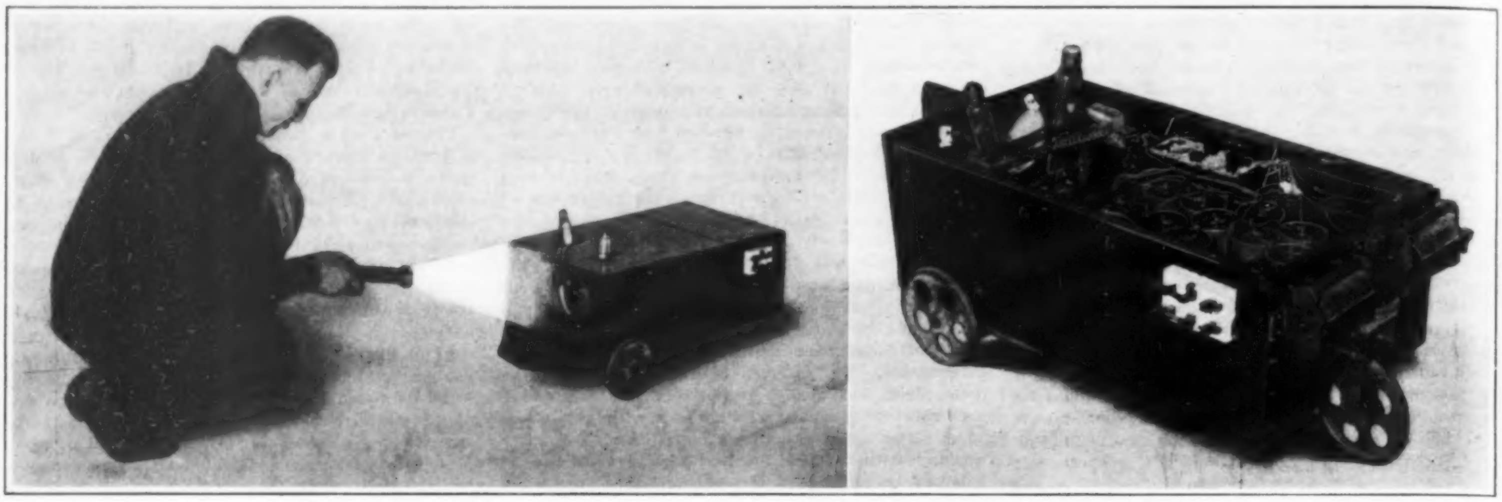
"The second method of experimenting was by looking at a white surface through a considerable length of water contained in a blackened tube. The light transmitted was found to be blue, thus showing the water to have a selective absorption for the rays of the red end of the spectrum.

(*Continued on p. 384*)

[2]I learn from a correspondent that certain Welsh tarns, which are reputed bottomless, have this inky hue.

[3]In no case, of course, is the green pure, but a mixture of green and blue.

[4]Aitken: Proc. Roy. Soc. Edin. 11, 472 (1882).



The Electric Dog following its luminous master, and a general view of its internal arrangement

The Electric Dog

Use of the Selenium Cell to Make an Orientation Mechanism

By Benjamin Franklin Miessner

THE principle of orientation is well exemplified in nature. A large variety of plants, flowers, and other living examples of the realm of botany, are endowed with the power of turning themselves for the purpose of gaining the beneficial effect of the sun's rays. A very common and good example of these is the sunflower, so named because of this well-defined ability to follow the path of the sun from east to west across the heavens.

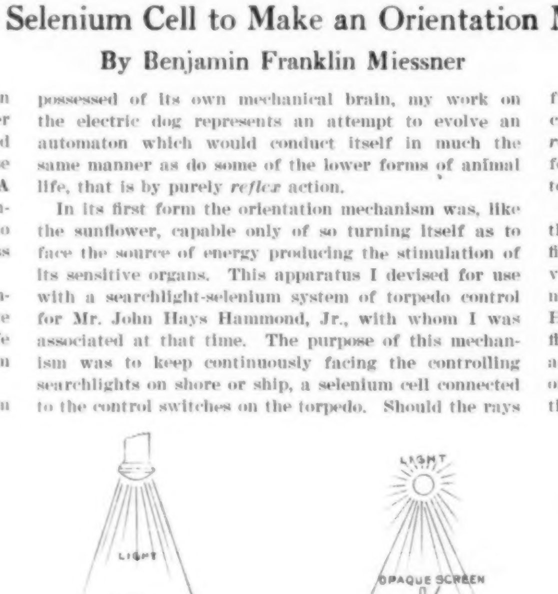
The mechanism herein described is merely an example of one of the many ways in which an inanimate object may be made to act like one possessed of life and as such capable of reacting like living objects from the effects of external stimuli.

Nikola Tesla, in a classic discussion, "The Problem of Increasing Human Energy,"[1] expressed the firm belief that every man, every living organism, is "merely an automaton endowed with power of movement, which responds to external stimuli beating upon its sense organs, and thinks and acts accordingly." He goes on to say: "With these experiments it was only natural that, long ago, I conceived the idea of constructing an automaton which would mechanically represent me and which would respond, as I do myself, but of course, in a much more primitive manner, to external influences. Such an automaton, evidently, had to have motive power, organs for locomotion, directive organs, and one or more sensitive organs so adapted as to be excited by external stimuli. This machine would, I reasoned, perform its movements in the manner of a living being, for it would have all the chief mechanical characteristics or elements of the same. . . . Whether the automaton be of flesh and bone, or of wood and steel, it mattered little provided it could perform all the duties required of it like an intelligent being. To do so, it had to have an element corresponding to the mind, which would effect the control of all of its movements and operations, and cause it to act, in any unforseen case that might present itself, with knowledge, reason, judgment, and experience. But this element I could easily embody in it by conveying to it my own intelligence, my own understanding."

In 1898 Tesla evolved the first practical telautomaton, which was in the form of a crewless boat that could be controlled from the shore or another boat by radiated energy. By means of this invention, which is the model from which all the wireless-directed torpedoes of today have been copied, Tesla was able to make an inanimate machine perform movements with the intelligence, reason, experience, and judgment of a living being.

This first automaton, it will be seen, was one which acted with the intelligence transmitted to it from the mind of its master, rather than with any intelligence which was an inherent part of its own makeup. Although, without a single doubt the intelligence of such an automaton as Mr. Tesla constructed, and which I in recent years have perfected for military purposes, would in any case be far superior to that of a machine possessed of its own mechanical brain, my work on the electric dog represents an attempt to evolve an automaton which would conduct itself in much the same manner as do some of the lower forms of animal life, that is by purely *reflex* action.

In its first form the orientation mechanism was, like the sunflower, capable only of so turning itself as to face the source of energy producing the stimulation of its sensitive organs. This apparatus I devised for use with a searchlight-selenium system of torpedo control for Mr. John Hays Hammond, Jr., with whom I was associated at that time. The purpose of this mechanism was to keep continuously facing the controlling searchlights on shore or ship, a selenium cell connected to the control switches on the torpedo. Should the rays



The arrangement of the electric dog (left), and a conventional representation (right) of the electric elements involved

of the enemy's searchlights reach the receiving selenium cell in sufficient intensity, interference destructive to the original control would result.

It is this problem of interference which has ever baffled the most advanced in this new art in their efforts to produce an automaton able to recognize the voice of its master absolutely and without fail despite the efforts of others to imitate or reproduce that voice in the minutest detail. It is this problem which has made necessary the national and international laws relative to the use of radiotelegraphic apparatus. It is, I think, a problem of constructing an automaton which is possessed of more than human intelligence, for that automaton must be able to recognize the call of its master, and not the imitations of others, however perfect they may be. We ourselves cannot perform such a feat. The only method which can be applied successfully in rendering an automaton susceptive only to the call of its master is *to prevent the calls of others from reaching it.* This the orientation mechanism has done for the searchlight-selenium or infra-red ray systems of torpedo control.

It was about the time of our first experiments with the orientation mechanism that Professor Jaques Loeb first announced the results of his experiments and investigations with moths and the reasons for the familiar attractive effect on them by sources of light. He found that the moth flies into a flame because its flight is automatically directed by some kind of reflex action due to the stimulation of light-sensitive organs on either side of its body. Professor Loeb found further that when one alone of these organs is exposed to illumination the moth experiences an unpleasant sensation that induces a reflex action which causes the moth to turn the exposed side of its body away from the light in its effort to dispel the unpleasant sensation. As soon, however, as the other side becomes exposed to the radiation, the pain and reflex action is again set up, the same cycle of events being repeated. The forward flight of the moth therefore carries it directly toward the source of light.

Here in the moth we have the case of a living automaton capable of orientating itself with respect to a source of radiated energy, and possessed at the same time with organs of locomotion, an automaton which performs its motions mechanically in response to external stimuli.

The next form of my orientation mechanism was a reproduction of the moth mechanism, that is, one which, like the moth, was provided with means of propulsion. In its present form the electric dog consists of a rectangular box about three feet long, one and one-half feet wide and one foot high. This box contains all the instruments and mechanism, and is mounted upon three wheels, two of which are geared to a driving motor; the third, on the rear end, is so mounted that its bearings can be turned in a horizontal plane for steering, much like the front wheel of a child's velocipede. Two large, glass lenses on the forward end, separated by a protruding, nose-like partition, appear very much like huge eyes.

If a pocket flash light be turned on the machine it will immediately spring into action, but will stop as suddenly if the light be snapped off or turned away. If the light be held stationary and directed upon the dog, it will ambie up until its own motion causes it to come directly under the light, and therefore into such a position that the light will not shine in its glass eyes; there it stops and the whining of its driving motor also ceases. If now one turns the flashlight into its eyes and walks about the room the dog will immediately respond and follow the moving light wherever it goes, with a loud metallic clank at each wag of its steering-wheel tail. This wagging of the tail occurs at every turn or every time at which, for any reason, the light fails to reach one of the great eyes. It always turns on these occasions so that the eye cut off from the light by the nose-like screen, will again see the light. So long as the light reaches both

[1] *Century Magazine*, June, 1900.

eyes in equal intensity, as when the source is directly ahead, the rear wheel is in the central position, and the dog moves ahead without turning. By turning over a switch, the dog can be made to back away from the light in a most surprising manner.

The electric dog is purely an automaton capable of self-propulsion and of self-direction, and the principle involved is applicable to any form of energy capable of transmission to a distance through the natural media. A suitable energy detector, which acts as the sensitive receptive organ, must be used; it must be capable, with the aid of auxiliary devices, of producing definite mechanical movements when influenced by the energy of the external stimulus. Thus, for visible waves in the ether, we use the selenium cell or its equivalent; with the infra-red or heat waves in the ether we use a sensitiye thermopile, bolometer, radiometer or other heat detecting instrument; for the ultra-violet, the trigger vacuum tube; for sound waves in air or dater, the microphone; for Hertzian waves in the ether, the radio detectors; in the case of Hertzian waves where the energy cannot well be directed as in the case of the other wave motions, the directive element must be incorporated in the receiver itself, that is, it must in all cases be so arranged that the direction from which the stimulating energy comes to it can be easily determined.

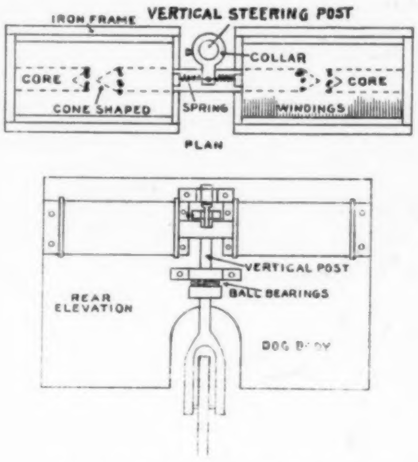
I have applied the Bellini-Tosi radio-goniometer and other radio direction finders as a means of determining the direction of the source of energy when electromagnetic waves are used. Two strongly directive antennae are supported with a certain small angle between their best directions for reception; each has connected to it a radio receiver terminating in a sensitive relay, and these control the dog mechanism exactly as do the selenium-controlled relays in the light-controlled dog. When the dog faces the source of the waves neither receiving set receives the full amount of energy; if for any reason the source moves or the dog changes its direction of motion, one of the receivers will receive a larger amount of energy while the other receives less; the result is that the balance is disturbed, a switch is moved to one side, and the steering apparatus is so operated as to bring the dog back into its original motion toward the source of energy. When refinements in radio direction finders are accomplished this form of electric dog will be well worthy of cosideration for a protection against intentional interference in torpedo control systems using Hertzian waves.

Automatic control of torpedoes has been made possible by the electric dog. Since 1911, when my experiments were materialized into the mechanism here pictured and described, I have developed plans for automatic torpedoes capable of following the sources of a number of different kinds of radiated energy, such as the sound waves resulting from the motion of a ship in the water, and from the ship's machinery, the heat radiated from its funnels, the light waves reflected from its surface. Every known form of energy capable of being radiated through the natural media has been considered in detail. Light waves and selenium were adopted in the present mechanism, because of the availability of suitable apparatus of sufficient sensitivity. I have recently given particular attention to radiant heat as the control energy and have succeeded in developing rugged and extremely sensitive receptive devices by means of which considerable simplification of apparatus and increased reliability are secured.

Although often demonstrated privately before interested scientific men in Gloucester and New York, the electric dog was first shown in public in a lecture-demonstration given by the writer on "Selenium, its Applications and Possibilities in Electrotechnics," before the Indianapolis Lafayette branch of the American Institute Electrical Engineers, at Purdue University, in January, 1915. I have devised numerous other applications of the electric dog principle, a rather novel one being an apparatus which will automatically control the pointing of guns, telscopes, and similar devices. Guns of the larger calibres, when used under the conditions imposed aboard ships, are much in need of some such automatic control. A master controller would effect the control of any or all guns on a ship merely by throwing in the connecting switch at each gun.

The electric dog follows a light, which quite naturally is surrounded by comparative darkness. In the case of the automatic torpedo or gun pointer this condition is completely reversed, that is, the source of attraction is a dark spot amid slightly brighter surroundings, or amid surroundings which are slightly different in their light-reflecting qualities.

The dog orients itself in a single plane, the horizontal; the gun pointer must be able to orient itself in both the horizontal and vertical planes simultaneously, and so must be provided with two sets of control apparatus, which operate in planes at right angles to one another. By providing telescopic attachments for the



Plan and elevation of the steering-wheel and its connections

selenium cells, the turret-turning and gun elevating motors may be controlled in such a way that the gun will always be pointed in the proper direction for effective firing at the distant target. As with the present system of manual control, the telescopic sights must be set in accordance with the measurements of range finders and spotters.

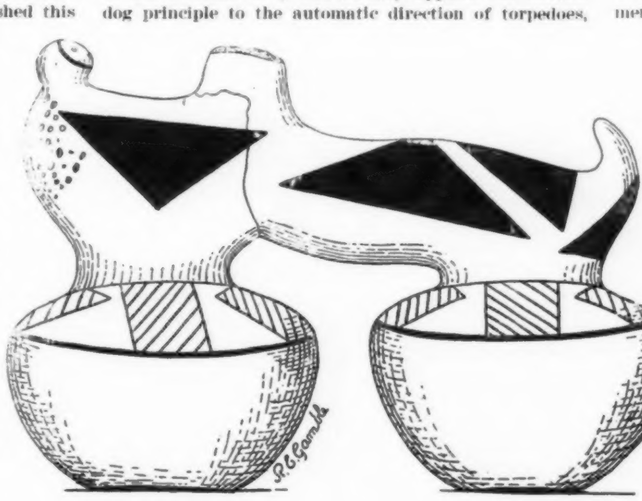
With such a double orientator a new defense against the submarine becomes possible. Captain K. O. Leon of the Swedish navy has already applied the electric dog principle to the automatic direction of torpedoes, the sound waves sent out through the water from the hull of a ship acting as the attracting stimulus, it is but a step to apply a double orientator of this type to torpedoes that will seek out and destroy any submarines within its range of hearing. This same type of automatic director is suitable for use with aerial torpedoes, explosive-laden mechanical moths, which will sweep down upon the ships of the air with a sting that will blow them into a thousand pieces. The electric dog which now is but an uncanny scientific curiosity may within the very near future become in truth a real "dog of war," without fear, without heart, without the human element so often susceptible to trickery, with but one purpose; to overtake and slay at the will of its master whatever comes within range of its senses.

A Unique Form of Prehistoric Pottery

The specimen of pottery here described was found by a farmer in cultivating his field near Dolores, in the southwestern corner of Colorado. The antiquities of this region show that it was inhabited in prehistoric times by a people who had made great advancement in architecture, on which account some of the best known examples of their buildings have been set aside by the Government for the permanent preservation of these remains. Some of the best known of these buildings are the cliff dwellings of the Mesa Verde National Park, but there are many others in form of castles and towers equally instructive situated in canyons and valleys west of this plateau as far as Utah. These skillful builders have left evidence of their superior craft far into New Mexico, at Aztec, and the large buildings along the Chaco Canyon. They characterize what is called the San Juan culture area, the horizon of which has not yet been determined.

This so-called San Juan culture area can be distinguished by ceramic as well as architectural features. Similar varieties of pottery are found over this whole area. In other words pottery and its decoration support architectural evidences of the extent of this culture area. We find the same technique, color, and design throughout. Foremost among the distinctive forms of pottery found in this area are the corrugated and black and white ware, types no longer manufactured and most abundant in early prehistoric times. We rarely find in this area imitations of human and animal figures in relief, a style of ceramic art quite common in northern Mexico and southern Arizona.

Several effigy vases have been collected from this area in the last few years, and it is probable that their numbers will increase year by year. The specimen here considered cannot be called an effigy base, but rather a rare double vase with handle decorated with rude representations of animals. It was plowed up a farmer, Mr. Littrell, while working on his land near Yellow Jacket Canyon about 5 miles south of Sandstone postoffice, 20 miles west of Dolores, Colo. The exceptional features of this object are shown in the accompanying illustrations. The vessel consists of two vases of equal size united by a handle, modeled in the form of a bird and another animal. The end of this handle to the left of the observer is a rude representation of the head and body of a bird. The orifice of the vase is on the back of this bird. The representation of the bird is very crude, but triangles similar to those generally painted on the sides of the body of birds are sometimes used in pueblo pictures to designate wings. Similar black figures of triangular shape also occur over the whole handle. The head is almost globular with dots representing eyes enclosed in a circle. The breast is spotted with black dots characteristic of bird and butterfly designs among the pueblos. An effigy vase with these symbols, undoubtedly representing a bird, was excavated last summer in a cemetery eight miles west of Sandstone Canyon.



The double vase described in the text, seen from side and from above

The posterior extremity of the animal represented on the handle of the two bowls could hardly represent the tail feathers of a bird, but might be intended for the tail of another group of animals, as quadrupeds. The handle can be interpreted as portions of the animals united; one of which is a bird and the other nondescript, both with one common body, a condition like that which characterizes some of the figures painted on the interior of mortuary bowls from prehistoric graves in the Mimbres Valley, New Mexico. In these are round figures of well-drawn fishes combined with an antelope or some nondescript animal combinations. Collections of pottery from Colorado and New Mexico show no designs where double animals are painted or molded.

The orifice of this double vase is situated in almost the middle of the handle, nearer that of the supposed head. It communicates with the cavities of both vases through the hollow handle and suggests that the object

(*Continued on p. 384.*)

The Races of Russia—II*

A Brief Outline of the Ethnic Background of the Czar's Former Domain

By Dr. Aleš Hrdlička of the U. S. National Museum

[Concluded from Scientific American Supplement, No. 2266, Page 365, for June 7, 1919]

After Rurik the bulk of Russian history consists of internal accommodations, not seldom violent; of defensive or retaliatory external wars; of endless, fluctuating life-and-death struggle in the south and southeast with the Asiatic hordes; and of unceasing extension of the prolific Slav element in all directions where resistance was not insurmountable. This was particularly toward the northeast and northwest, where gradually the Meria, Mordva and other primitive Finnic tribes were replaced or in a large measure absorbed.

Notwithstanding the many internal and external vicissitudes of the country, its elementary spread continued until 1226, when all southern Russia fell under the greatest blight that had yet afflicted it, through the final and overwhelming Tartar or "Mongol" invasion. This invasion covered all present Ukrainia and beyond, and thence extended over parts of Poland, Galicia, and Hungary. The southern Russians were slaughtered in large numbers and subjected to the Tartar yoke or forced to flee. The southern and southwestern parts of Russia became seriously depopulated and were occupied by the roaming Tartars of the "Golden Horde;" and Russia as a whole suffered from the effects of the invasion for over two centuries. The invaders established themselves over much of the southern part of the country, particularly in Crimea, where they became a fixed element and developed a political unity of their own, which remained ruled by their Khans until 1783, the year of their final submission to the Russians. To this, however, a large part of the population of Crimea is more or less Tartar.

Long before this, however, the Russians spread over all the more northern regions of their present European domain, to and beyond the Urals, and even over Siberia. Expansion into the latter deserves a few words by itself.

Up to the sixteenth century the vast region now known as Siberia was peopled exclusively by native tribes, of Ural-Altaic or Mongolian extraction or with Mongolian admixture. They were all more or less nomadic and in a primitive state of culture. There was never any political unity; and many of the tribes whose forefathers had probably participated in the westward invasions lapsed gradually into a numerically and otherwise weakened condition. It was such a state of affairs which awaited the ever progressing Russian tide.

The first Russians crossed the Urals as early as the eleventh century, but this led to no consequences of importance. The conquest of Siberia took place in 1580. Yermak, a Don Cossack in disgrace, invaded the vast territory with 1,636 followers, and this handful of men practically secured the conquest of a territory considerably more than twice as large as the whole of Russia in Europe. Within eighty years after that the Russians reached the Amur and the Pacific; and the rest is merely a history of a gradual disappearance of the natives and of Russian immigration.

The cultural progress as well as the racial aspects of southern Russia was affected more by the great Tartar invasion of the thirteenth century than by any or perhaps all the previous ones. The descendants of the Tartars, together with other remnants, are found to this day in numbers along the Volga and some of its tributaries, and north of the Sea of Azov, as well as in Crimea and the Caucasus; while some Tartar blood can be traced in not a few Russian familes. The effects of the resulting ethnographic changes are felt even now and have been utilized by the enemies of Russia against the interest of the country. This relates especially to the region now known as Ukraina (the "border province") or Little Russia. No such subdivision existed before this last Tartar invasion, and the region of Kiev, now the capital of Ukraine, was the old center and heart of Russia. The Tartar massacres in part depopulated the region, and created a terror which resulted in large numbers of the people fleeing westward into Galicia and Polish territory. There are differences of opinion as to how great the depopulation really was, but that it was severe, though perhaps not complete, is indisputable. As all this is of particular importance at the present time it may be best to quote here from one of the foremost modern Russian historians who gave this question particular attention:[1]

"The exodus from Kievan Rus took two different directions, and flowed in two different streams. Of these streams, one tended towards the West—towards the region of the Western Bug, the upper portions of the Dniester and Vistula, and the interior districts of Galicia and Poland. This westward movement had a marked effect upon the fortunes of the two most outlying Russian provinces in that direction—namely, Galicia and Volhynia. Hitherto their position in the political hierarchy of Russian territories had always caused them to rank as lesser provinces, but now Galicia —one of the remote districts allotted only to *izgoi* princes of the house of Yaroslav—rose to be one of the strongest and most influential in all the southwestern region. The '*Slovo o Polpu Igorove*' even speaks of the Galician Prince of its day (Yaroslav the Prudent) as 'rolling back the gates of Kiev,' while, with the end of the twelfth century, when Roman, son of Mstislav, had added the province to his own principality of Volhynia, the combined state waxed so great in population and importance that its princes became sufficiently rich and powerful to gather into their hands the direction of the whole southwestern region, and even of Kiev itself. In fact, the Ancient Chronicle goes so far as to describe Prince Roman as 'the Autocrat of all the Russian land.' Probably, also, this inrush of Russian refugees into Galicia and Poland explains the fact that annals of the thirteenth and fourteenth centuries frequently refer to Orthodox churches as then existing in the province of Cracow and other portions of the Southwest.

"The same migratory movement may serve to throw light upon a phenomenon of great importance in Russian ethnography—namely, the formation of the Little Russian stock. The depopulation of Dnieprian Rus which began in the twelfth century was completed during the thirteenth by the Tartar invasions which took place between the years 1229 and 1240. For a long period after the latter date the provinces of ancient Rus, once so thickly peopled, remained in a state of desolation. A Catholic missionary named Plano Carpini, who traversed Kievan Rus in 1246, on his way from Poland to the Volga to preach the Gospel to the Tartars, has recorded in his memoirs that, although the road between Vladimir in Volhynia and Kiev was beset with perils, owing to the frequency with which the Lithuanians raided that region, he met with no obstacle at the hands of Russians—for the very good reason that few of them were left alive in the country after the raids and massacres of the Tartars. Throughout the whole of his journey across the ancient provinces of Kiev and Periaslavl, he saw countless bones and skulls lying by the wayside or scattered over the neighboring fields, while in Kiev itself—once a populous and spacious city—he counted only two hundred houses, each of which sheltered but a few sorry inmates. During the following two or three centuries Kiev underwent still further vicissitudes. Hardly had she recovered from the Tartar attacks delivered prior to the year 1240 when (in 1299) she was ravaged afresh by some of the scattered bands of Polovtsi, Pehhenegs, Turks, and other barbarians who roamed her desolate frontiers. In that more or less grievous plight the southern provinces of Rus remained until well-nigh the middle of the fifteenth century. Meanwhile Southwestern Rus (now beginning to be called in documents of the period 'Malaia Rossia' or 'Little Russia') had been annexed to the combined state of Poland-Lithuania; so that of the Empire thus formed the region of the Middle Dnieper—*i. e.*, old Kievan Rus —had now become the southeasternmost province or Ukraine. With the fifteenth century a new colonisation of the Middle Dnieper region began, to which two circumstances in particular contributed: namely, (1) the fact that the Steppes of the South were becoming less dangerous, owing to the dispersal of the Golden Horde and the rise of Muscovite Rus, and (2) the fact that the Polish Empire was beginning to abolish her old system of peasant tenure by quit-rent in favor of the *barstchina* system, which tended towards serfdom and therefore filled the oppressed rural population with a desire to escape from the masters' yoke to a region where they might live more freely. These two factors combined to set on foot an active *reflex* exodus from Galicia and the central provinces of Poland towards the southeasternmost borders of the Polish Empire—*i. e.*, towards the region of the Dnieper and old Kievan Rus. The chief directors of this movement were the rich Polish magnates, who had acquired enormous estates in that part of the world, and now desired to people and reclaim them. The combined efforts of the immigrants soon succeeded in studding these seignorial domains with towns, villages, hamlets, and detached homesteads; with the result that we find Polish writers of the sixteenth century at once exclaiming at the surprisingly rapid movement of colonists towards the Dnieper, the Dniester, and the Eastern Bug, and lamenting the depopulation of the central provinces of Poland to which that movement had given rise. All things considered, there can be little doubt that the bulk of the settlers who took part in the recolonising of Southern Rus were of purely Russian origin—that, in fact, they were the descendants of those very Russians who had fled westwards from the Dnieper during the twelfth and thirteenth centuries, and who, though dwelling since among a Polish and Lithuanian population, had, throughout the two or three intervening centuries, retained their nationality intact."

The language of the new population of Ukraina developed certain dialectical differences, while in other parts of Russia it was being gradually affected in other ways by association with the Lekhs (Poles), Lithuanians, and the Finnish tribes. In addition there arose in the course of time, as could hardly be otherwise when the great territories over which the Russian people were spread are taken into consideration, some differences in the richness and nature of folk tales, folk poetry, dress, etc.; differences the perception of which by the Ukrainians has for long before the present war been assiduously fostered by the Germans and Austrians, on the basis of their cherished, old "*divide et impera*" principle. Finally this region has received, together with Bessarabia, the mass of the Jewish immigration into Russia, which could not but add to its separatism, for which anthropologically and outside of the Jews there is no substantial reason.

At about the same time that the terms of Ukrainia and Mala Rossia ("smaller Russia") came into vogue, there also began to appear those of Velika and Biela Rossia ("Greater, and White Russia"), and those of Malorusi, Velikorusi and Bielorusi, which are applied to their respective populations. These terms, like those of Ugro-Rusi, Rutheni, Gorali, etc., are partly conventional, partly environmental or geographical. The language and habits of the Bielorusi, who occupy the westernmost part of Russia north of Ukraina, were gradually affected, though on the whole to but a moderate extent, by their relations with the Poles and Lithuanians; while those of the Velikorusi or "Moskvali" (Muscovites) who spread over central, northern and eastern Russia, were modified somewhat in turn by their associations with the Tchouds, Finns, and various other people of the Finno-Ugrian stock with whom they mingled and whom they freely absorbed.

Such were in very brief the origin and nature of the three great subdivisions of the Russian people with which we meet today. The resulting differences between them, both cultural and somatological, are smaller than those between some of the tribes of Germany, and had it not been for Russia's enemies in whose interest it was to foment dissensions in the population, they would have remained harmless and with growing culture would have disappeared. But powerful united Russia, such as it could have been and with the help of the Allies may yet be, was an insupportable nightmare to both Austria-Hungary and Germany.

From the purely anthropological standpoint, the Russians belong overwhelmingly to the great type of Slavs in general, which in turn can hardly be distinguished from the Alpine type. But, like all large nationalities, the Russians show in various localities more or less marked traces of admixture with the Nordic peoples on the one hand, and on the other with the Finnish, Turkish, Tartar, and Iranian tribes.

The modern Russian population represents a physically strong and very prolific stock, freer as yet from degenerative conditions than perhaps any other of the larger European groups. The total population of European and Asiatic Russia counted collectively at the commencement of the war 178,000,000, living in a continuous mass and increasing yearly, through the natural excess of births over deaths by over 1.67%, the highest rate of any more important white population. The Slavs constitute approximately 75% of this population—81% in European Russia and Poland, 40% in Caucasus, and 85% in Siberia. As to the proportion

*Smithsonian Misc. Coll., Vol. 69, No. 11.

[1] A History of Russia, by *V. O. Kluchevsky*, late professor of Russian History of the University of Moscow, 3 vol., 8°, 1911-13; I, 194-196.

of the separate Slav and other racial elements, we have the interesting and trustworthy estimates by Professor Niederle of Prague, the foremost authority on Slav matters in general.[2]

THE NON-RUSSIAN RACES OF EUROPEAN RUSSIA.

These include the Poles, the Lithuanians, the Tchouds and Finns, the remnants of the Finno-Ugrian tribes of the interior, the Laps and the Samoyedes, the Tartars, the tribes of the Caucasus, and finally the immigrant Jews and Germans. In the first place, however, a few remarks may be appropriate here regarding the Cossacks.

The Cossacks.—The term Cosack has in the course of time become surrounded, even in Russia itself, with a semi-romantic and heroic halo, which is not wholly undeserved; but the term itself is seldom properly understood. The Cossacks of the present day may be defined as a special class of irregular, privileged cavalry. The Kazaki (the Russian form of the term) of the fifteenth and sixteenth centuries were in part a class of irregular agricultural help "who possessed neither a definite avocation nor a settled domicile," in part frontiersmen and adventurers, along the southern boundaries of the Russian settlements. The word Cossack came to signify, in Kirghiz, a cavalier, in Tartar a freebooter, in Turkish a light-armed soldier; they were all this and more. They were of Russian origin; but being always settled on the outskirts of the advancing empire and continuously in struggle or contact with the Turkish and Tartaric hordes, their blood has received in the course of time more or less admixture. Some of the Cossacks now are recruited in the main from non-Russians.

The fighting Cossacks as far as traceable originated during the fourteenth or fifteenth century from among the Russian refugees before the invading Tartars. They settled on certain islands in the Dnieper River, were hunters, fishermen, and Tartar fighters, and gradually developed into a strong, bold, and resistant group, loving the hard frontier life with its liberties and dangers. Similar bodies developed all along the border of the steppes and became the terror of the Tartars and Turks, though frequently also a trouble to the Poles and even Russians. Their military value was, however, generally recognized in time and led to the regulation and extension of the Cossack system over southern Russia, Caucasus, Central Asia, and Siberia, until the Cossack became the regular forerunner, scout, and protector of the Russian armies and Russian colonies from the Danube to the Pacific Ocean.

There exist today about twelve subdivisions of the Cossacks, the best known of which are those of the Don, Orenburg, Ural, and Siberia. Their free institutions, interesting customs, and especially their exploits in the conquest of Siberia, the Napoleonic invasion, etc., made their name justly famous.

The Poles.—The Poles, the old "Lekhi" and "Poliane," are Slavs derived in prehistoric times, like the Russians, Czechs, etc., from the common autochthonous Slav nucleus north of the Carpathians. They are admixed somewhat with the Russians and to some extent also with the Lithuanians; slightly, perhaps, also with nordic and other elements. At the commencement of the war they numbered in European and Asiatic Russia approximately eleven millions, almost ninetenths of which were in Russian Poland.[3] Notwithstanding their thousand years of agitated history, they are still a "young" stock, full of energy, ability and spirits, and as prolific as the Russians.

The Lithuanians.—The Lithuanian territory lay originally along the Baltic between the Visla (Vistula) and Dvina, and at the time of their maximum power their influence reached from the Gulf of Riga to Ukraina. They extend at present from Poland and east Prussia to near Riga.

The Lithuanians are a strain of people whose racial identity has been a matter of considerable controversy. Through their ancient tongue, which has many similarities with the Sanscrit and with the Slav, they are related most closely to the latter, but in physical type while resembling the Poles and Great Russians they also approximate in part the Scandinavians on account of more frequent blondness. In all probability they have an admixture of all these elements. They are subdivided into three main branches, the Borussians (Prussians), the Latvis or Letts, and the Litvini or Lithuanians proper. Their total number at present is slightly over four millions, about equally divided among the Letts and Lithuanians. The Borussians, whose home was in eastern Prussia, were almost destroyed by the Germans in the thirteenth century, under the pretext of Christinanization. In the words of one of the German writers himself (Schleicher, 1852), "Never has a pagan people, good, brave and generous, been maltreated in a more cruel manner than the eastern Prussians. . . . The history of their death struggle against the Teutonic order must be mentioned as one of the most sinister episodes of mankind." A few remnants of them still exist in Eastern Prussia.

The Lithuanians, whose ethnographic limits are ill-defined, have been connected with Russia since 1797.

The Livonians.—The true Livonians are practically extinct. Their country lies east of the Gulf of Riga and is now occupied partly by Letts and partly by Esthonians. Their language belonged to the Finnish or Finno-Ugrian family, and they were doubtless closely related to the Esthonians.

The Tchouds or Esthonians are a Finnish tribe occupying a larger part of the territory between the Gulf of Riga and the Gulf of Finland. They have been united with Russia since 1030, but were tributary to the Russians much earlier. They number at present only between five and six hundred thousand persons. Efforts by the Germans since the thirteenth century at "Christianizing" Livonia and Esthonia, as they did Prussia, have been a failure, and "the Ehsts and Letts openly display their traditional hatred against the invaders."

The Finns.—The Grand duchy of Finland was ceded by Sweden to Russia in 1809. Its population consists at present of approximately 2,700,000 Finns, 350,000 Swedes, 8,000 Russians, 2,000 Germans, and 1,700 Laps. The Finns represent the westernmost extension of the Finno-Ugrian Asiatic stock; but while retaining their language their blood, especially in the south, has become much mixed with that of the Scandinavians. The more northeastern subdivision of the Finns, known as the Karelians, are better preserved.

The Laps and Samoyeds.—These are the most Mongolic-like natives of European Russia and are undoubtedly of Asiatic origin. Their numbers are insignificant—collectively less than 20,000 individuals. They occupy the northernmost limits of the Russian territory, the Laps extending into Scandinavia.

Finno-Ugrian tribes of the interior.—These are located principally on the middle Volga and the Kama, and represent the dwindling remnants of the primitive native populations that once covered much of central and eastern Russia. They have long been without any political individuality and are in a more or less advanced stage of absorption into the Russian population. They are known principally as the Mordva, Tcheremis, Voguls and Votiaks.

The Turko-Tartars.—Of these there are approximately seven millions in European Russia and the Caucasus. They are divided into the Crimean Tartars, Kazan Tartars, the Bashkirs, the Tchuvash and the Kirghiz, with many minor units. They still occupy or wander over a large portion of southeastern Russia and except within the diverse groups have no political or racial cohesion.

Caucasus.—This region since ancient times has been the eddy and refuge of remnants of nations, and there are in its fastnesses many interesting units which it is difficult to classify. By far the strongest element of the Caucasian population today, however, is the Slav (approximately 40% of the total), which is followed by the Turco-Tartar, Georgian, and Armenian. The total population of Cis- and Trans-Caucasia may be estimated at present at something over 13,000,000.

Siberian Natives.—Today Siberia or more properly Asiatic Russia, possesses nearly eleven million inhabitants, considerably less than one-tenth of whom are non-Russians. Of these approximately 500,000 are Turko-Tartars, 300,000 Mongols, 70,000 Tungus, and 35,000 Ghiliaks, Chukchis, Koriaks, Yukaghirs, Kamchadals, Eskimo, and other smaller units; but all these groups are more or less mixed with the Russians,[4] and with the exception perhaps of those in Turkestan have no individualistic aspirations.

The Jews.—The Russian Jews are in the main, if not entirely, the descendants of refugees driven out of Germany during the persecution of the race in the middle ages. Some Jews penetrated into Poland and Lithuania as early as the middle of the eleventh century, but by far the larger number came later, particularly under the Polish king, Casimir the Great, whose wife was of Jewish extraction. From Poland they spread to Lithuania, Courland, and what is now Ukraina and Bessarabia. Peter the Great, and particularly Catherine II, opened to them the door of Russia.

A small branch of the Russian Jews are known as the Karaites. They differ in many respects from the remainder, are settled in Crimea where they speak Tartar and in western Russia where they speak Polish, and are principally agricultural. Their origin is still in dispute.

The total present number of Jews in European Russia before the war approximated 4,000,000, in Russian Poland 1,300,000, and in Caucasus 50,000. In addition there were about 50,000 in Siberia and Central Asia.

It is very interesting to note that physically the Russian Jews of today resemble to a considerable extent the Russians themselves.[5] In Poland the approximation of the two types of population is much less apparent. The Karaites, whom some suppose to be the descendants of the Khazars, show anthropologically some affinity with the Tartars.

The Germans.—The total number of Germans in the lands under Russian dominion amounted to a little over 1,800,000 in 1914. They were scattered over practically all except the poorest parts of the empire, especially in the cities. In the Baltic provinces they were the privileged landed proprietors. In southern Russia and other agriculturally rich regions there were German agricultural colonies, some recent, some of older formation.

The German influx into Russia started in the sixteenth century and was specially active during the reign of Peter the Great. They came as artisans and merchants, frequently on invitation; and in 1762 they were invited to settle in some parts of southern Russia in agricultural colonies, which gradually and in a scattered way extended to the Don and the Caucasus. These colonies received special privileges, were practically self-governing, and fused but little with the Russians. During the latter half of the nineteenth century German colonization in important parts of Russia was, there are valid reasons to believe, favored if not directed by the German Government.

The German nobles and landed proprietors in the Baltic provinces date in the main from the time of the attempts by the German Knights to forcibly "Christianize" the natives of these provinces, though some were brought there later by the guileless Russians. . . .

Concluding Remarks.—Leaving aside all details and localized ethnic peculiarities, we find that the racial problems of European as well as of Asiatic Russia, are relatively fairly simple. (1) We find over a large portion of the vast territory a thin substratum of Finno-Ugrians, who are of western Asiatic origin and carry with them varying traces of Mongolian admixture. (2) The southern portions of Russia from remote time constitute a broad avenue for the movement of Asiatic peoples in a westerly direction. These peoples are partly of Iranian, but in the main of Turko-Tartar derivation; and the Turko-Tartars like the Finno-Ugrians are mixed peoples, partly white and partly Mongolian. Their influence, both racial and cultural, on the country and its people is marked and in a measure persists even to the present day. (3) Along the Baltic we find Finnish tribes in the north and the Lithuanians, probably of mixed Slavic and Scandinavian composition, farther southward and westward. (4) All the rest of the great region is Slav, Polish in the west, Russian in the center and eastward.

It is eminently true that Russia is essentially a Slav country, which today is equally true of Siberia and in a large measure even of the Caucasus. In Central Asia the Russian element is still considerably exceeded by the Turco-Tartars.

From the anthropological standpoint, the Russian stock is well developed, virile, resistant, and full of potential force. It may truly be said to be the great human reserve of the European population. If it has not advanced in culture as much as the western and southern European nations, the causes if contemplated impartially are seen to have been not inherent or racial, but geographic and circumstantial. It must not be forgotten that Russia by acting from its inception as the buffer between the rest of Europe and Asia, and by becoming later the principal check of the Turk, has deserved a deep gratitude of the more western and more favorably situated nations.

What will be Russia's future? Perhaps the anthropologist may attempt to predict where others would hesitate.

The Russian Slavs taken collectively, count today over one hundred millions,[6] and they are increasing yearly, by the excess of births over deaths by 1,700,000. This rate of increase is greater than that of any other people in Europe except some of the other branches of the Slavs, and with the mass of the people belonging to the conservative simple-lived rural population, cannot be expected to become much reduced in the near future. Such a rate of increase of this otherwise strong and able portion of the white stock, means a biological momentum which in the end must prevail over all opposition. . . .

[2] *Lubor Niederle*: Slovansky Svet. 8°, Praha, 1910; abstr. in Smithson. Rep. for 1910, pp. 599-612, with a map.

[3] Those of Austrian-Poland counted in 1914 approximately 4,500,000; those of German-Poland approximately 4,000,000.

[4] An excellent ethnographic map of Siberia has been published, together with two large volumes of descriptive text, by the Dept. of Agriculture of the Russian Government in 1914 ("Etnograficheskaia Karta Asiatskoi Rossii").

[5] Compare Maurice Fishberg, The Jews, N. Y., 1911.

[6] See author's article "The Slavs" in the *Czechoslovak Review*, vol. 2, Chicago, Nov. 1918, p. 180-187.

The Shell Builders—III

A Brief Introduction to the Study of Conchology

By R. W. Shufeldt, M.D.

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In various places throughout Parts I and II of the present contribution to popular conchology, attention was invited to the great number of shells, the vernacular names of which are those of some object that the shell seemed to resemble, to the mind of the one naming it. As a matter of fact, throughout the entire range of animate and inanimate nature, since the very birth of biology, man has frequently bestowed the name of one species or structure upon that of another, whenever the latter in some way reminded him of the first or of the form with which the world was more or less familiar. This is the case not only all through scientific terminology, but may as often be observed in the vernacular. Sometimes it is the entire form that impresses this resemblance; or it may only be some special part—a fact well exemplified, for instance, in human anatomy, where a very large percentage of the names and structures have, since the earliest times, borne the names of material things. An excellent illustration of this may be seen in the collar-bone, technically known as the *clavicle*, which is derived from the Latin *clavicula*, the diminutive of *clavis*—a key. The *sternum* or breast-bone is likened to a gladiator's sword with its three usual divisions, namely the "manubrium," the "gladiolis," and "xiphoid extremity;" and so on throughout not only man's body but the body of every other animal. Conchology is specially rich in this respect, and nowhere more so in that science than among the ocean shells.

In going over the splendid collection of shells in the United States National Museum—numbering many thousands of specimens—for the purpose of selecting desired examples for photography, the truth of what is set forth above is continually noted as specimen after specimen is examined. As tray after tray filled with all sorts of curious shells of oysters are passed in review, we come presently to the species which has aptly been christened the Hammer Oyster (*Malleus vulgaris*). This is the Common Hammer Oyster, to distinguish it from the White Hammer Oyster (*Malleus albus*, Fig. 30) of the Philippines, the first-named species being found in the China Seas. Lamarck named it, and doubtless he at one recognized its resemblance to the common tool we call a hammer. *Malleus* is the Latin for hammer; and in the old French we have *mal* from which *mallet*, a wooden hammer, is derived. As a matter of fact, this shell certainly looks wonderfully like an upholsterer's hammer.

Curiously enough, it seems to be the bivalve group which furnishes the majority of those species that have received names indicating their resemblance to certain more or less familiar objects. It is needless to say that these Hammer oysters belong in that group, which is also true of the remarkable clam from the Isle of Man, here shown in Figs. 31 and 32. When held as in Fig. 31, it presents the exact outline of the conventional heart, which led Linnæus to name it *Isocardia cor*, both generic and specific names inviting attention to its cordate outline. This is lost to the eye when the specimen is turned as in Fig. 32, when the conspicuous beak or umbo on either half of the shell is brought into view. *Isocardia lamarcki* (Fig. 35) has the beak on each shell very beautifully developed, and this species also resembles a heart when properly held before one. The same is true of *Hemicardium monstrosum* from China (Fig. 34)—a very curiously formed species. Other bivalves have been likened to still other structures, both real and imaginary. Among these we have the extremely beautiful species of the genus *Dione*, as the *Dione dione* from the northern coasts of South America and those of Nicaragua and Trinidad (Fig. 36), and the still larger and more elegant form from Australia (*Dione veneris*), where this genus of shells centers. Those in the imaginary class are well exemplified by the bivalve called "Angel Wings" (*Pholas costatus*, East America, Fig. 37), which, when its two halves are slightly parted—the "hinge" being duly luxated—have by some been likened to a pair of angel's wings. [This resemblance appears when the top of our page is held in one's left hand.]

Passing to the univalve shells, we meet with a great many examples to illustrate this subject. Harp shells of the genus *Harpa* have, by their general outline and series of raised subparallel ribs, suggested to many people a harp, and this fancied resemblance seems to be destined to pass down the ages. They are Old World shells of a very limited number of species—not over ten. One of the handsomest of the group is the Imperial Harp shell (*Harpa imperialis*, Fig. 33) of Mauritius. All these forms have superb coloring and a high gloss, while their contours have a special charm not easily described.

Hammer Oyster (Malleus albus), from the Philippines

It requires a keen imagination to see a woodcock's head in the extraordinary shell shown in Fig. 38 (*Murex scolopax*, Red Sea); still, it is claimed that the head and bill are there, the dark area of the aperture standing for the eye. This shell is known as the Thorny Woodcock; while a related species, having still more conspicuous spines, is called Venus' Comb. Hundreds of other examples might be cited to illustrate this interesting subject. Among them may be mentioned the spider shells, dolphin shells, mitre shells, otter shells, slipper shells, razor clams, pelican foot, turk cap, the horse hoof, egg shells, fig shells—in fact, myriads of others, the whole presenting a list altogether too extensive for record in the present article.

Some of the shells here figured have already been referred to in Parts I and II, e. g. the curious Thorny Woodcock (*Murex scolopax*) and the Harp shell, here shown in Fig. 33 (No. 2263 for May 17, 1919). In the case of the latter, however, it was not posed in such a way as to show the fancied resemblance to a harp as is the case here. In Fig. 33, too, we may see the beautiful banding on the dorsum of this elegant shell, and other characters.

There is a very complete collection of the Hammer Oysters in the Division of the Mollusca in the United States National Museum, and it was an enjoyable privilege to examine the series. *Malleus*, as a genus, contains but very few species, and these appear to be confined to certain of the Australian and China seas. *Malleus albus* is a Philippine form; it is of a more delicate conformation, in which the valves are white. Specimens have been collected exhibiting a length of ten inches.

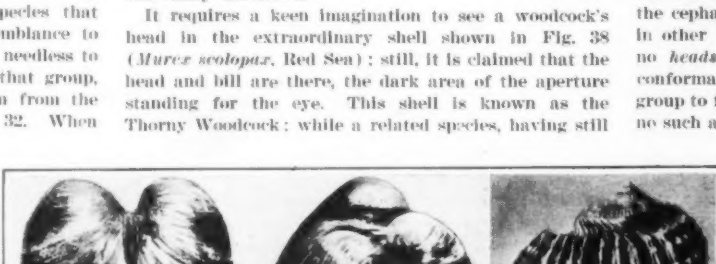
It is along certain coasts of China that we find the Common Hammer Oyster, and it is of a much greater size than the white species, which rarely exceeds eight inches in length. Essentially coarse in structure, the valves of this curious Common Hammer Oyster are thick in full-grown specimens and sometimes exhibit considerable curvature, with an oblique slant to one side or the other from the hinge. As to color, the undulating valves are usually of a deep gray, or even black. Miss Rogers has pointed out that in "early life the shell is like those of Avicula, and the byssal cord passes out through a deep sinus in the right valve. Later, the extension of the valve in three directions gives the characteristic form, and the byssal sinus is midway between the two valves, causing an indentation in each. The lining shows that the body lies in a roundish space near the hinge, attached by a large muscle scar." I noted in some of the National Museum specimens that the lining was very dark, almost black, and of a glossy pearliness.

Comparatively recent reports state that forms of these Hammer oysters have been discovered in which the cephalic lateral extension of the valves is lacking; in other words, that these bivalve "hammers" possess no *heads*. These new species are of very irregular conformation; and had they been the first of the group to fall into the hands of descriptive conchologists, no such appellation as *Malleus* would have been awarded the genus.

Some odd-looking bivalves are to be found among the Cyprinas of the family *Cyprinidæ*; one of these is well shown in Figs. 31 and 32, which, when held in a certain position, as pointed out above, exhibits the outline of the conventional heart. Since Linnæus gave this species the name of *Isocardia cor*, another species has been discovered in the China Seas; it has been named *Isocardia vulgaris* by Reeve, who also described *Isocardia lamarcki*—that is, if these two shells are of different species. One of the most curious characters presented on the part of the species of this genus is the manner in which the beak on either valve gracefully curls around to form a conspicuous spire, thus adding a very interesting and unusual character to either valve of the heart shells. Most of the *Cyprinidæ* are fossil species, the Iceland Cyprina (*C. islandica*) apparently being the only existing species. This small type of only three or four inches in length has, at varying intervals, been washed up on the shores of New England, especially after heavy gales.

Another Cockle or Heart shell is here shown in Fig. 34; when photographed, however, it was not, as I have stated, posed in such a way as to show what a

Heart-shaped Clam (Isocardia cor) from Isle of Man; on right an Imperial Harp shell (H. imperialis) from Mauritius. (Figs. 31-33)



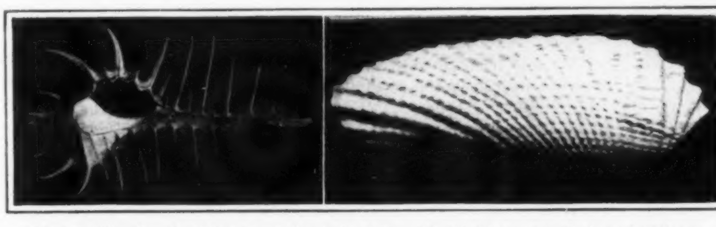
Hemicardium monstrosum, from China; Isocardia lamarcki; The Venus shell (Dione dione), from Nicaragua and Trinidad. (Figs. 34-36)

perfect "heart" it presents to the eye of the observer.

The *Hemicardium monstrosum* of the China Seas appears to be a recent discovery, as it is not mentioned in the popular works on conchology of the times—not even the genus being given. Only a few specimens of it were available in the National Museum. They are of a very delicate structure and of a pale, creamy color. As a group, the "Cockles" of the genus *Cardium* is an extensive one, consisting of at least one hundred species having cosmopolitan distribution.

Reference has already been made to the bivalve called "Angel Wings" (*Pholas costata*, Linn., Fig. 37), it being one of the "Piddocks" of the family *Pholadidæ*. There are several genera in this group in addition to *Pholas*, as *Xylophaga*, *Zirphæa*, and *Pholadidea*, many of the species of which are likewise called Piddocks. Various fossil forms of this family have also been described, and they doubtless had habits which are still characteristic of the existing types. Most prominent among these are their rock-boring proclivities. All of the piddocks have a way of drilling into submerged clay-banks and bottoms, or logs of wood which have long been under water. More extraordinary than this, however, is the habit these bivelves have of actually perforating rock in this manner, their drillings being very symmetrical and individualized. It is of the rarest occurrence to meet with two perforations that cut into or are even longitudinally tangent to each other.

Species of the genus *Pholas* possess luminous properties,—that is, they shine in the dark, much as do certain forms in the insect world.



Horny Woodcock (Murex scolopax), from the Red Sea; and Angel Wings (Pholas costata), from Eastern America. (Figs. 38 and 37)

When duly hinged, *Pholas* is a cylindrical bivalve in contour, with anterior and posterior accessory valves protecting its dorsal margin and concealing the beaks. The shell also gapes at its two extremities. The valves being attenuated and chalky white, the whole possesses a delicacy of an unusually striking character.

Pholas costata is found along the Atlantic coast from Massachusetts to Florida, being of rare occurrence northward above Virginia. In the southern part of its range it is usually found in colonies, which burrow down into the sandy mud for a foot or so, though it is not usual to meet with such colonies in burrows in rock and wood.

Piddocks of various species are often pickled in vinegar, and when so preserved they are relished by the inhabitants of the coast of Normandy; elsewhere they are used for bait as well as for food. In their very young stages Piddocks are free to move about at will; but they soon begin to exercise their boring powers and excavate their burrows, which they apparently inhabit for the balance of their lives, or at least until man digs them out for his own use.

The rough, file-like surface on the shell is shown in our photograph and it is by means of this that the mollusk is able to grind its way into solid rock—a truly marvelous feat. When boring the Pholas rotates on its longitudinal axis, holding itself in position through the suctorial powers of the foot, which is truncated anteriorly, of considerable size, and very strong. Seizing grains of sand with this foot, the piddock manages to start its burrow by a grinding process at the chosen point of entrance. Once inside the completed burrow, the incarceration ends only when some enemy of the mollusk forcibly pulls it out—otherwise it is quite as "happy as a clam at high water." Its long siphons are employed to secure both oxygen and food; and they remain unimpaired, as a rule, unless some prowling crustacean or starfish comes along and snips them off, in which case the mollusk will have good reason to use its "angel wings." This species is sometimes called the "Ribbed Pholas," and I have seen them in Cuba at the old Havana markets where they were sold as food.

The truncated Piddock (*P. truncata*) is also common in some places along our Atlantic coast, sometimes being found in the same localities as *P. costata*. Then on our West coast we find the California Piddock (*P. californica*), which is a species quite distinct from the Atlantic coast forms.

In various seas of Europe there lives a mollusk whose shell is frequently found in collections, and which has long been known as the Pelican's Foot (*Aporrhais pes-pelicani*) on account of its peculiar form. It certainly is a very odd-looking shell; and there are those who believe that "the four webbed toes of a pelican's foot are certainly suggested by the modifications of this shell's outer lip. The toes and their webs extend backward, covering a considerable portion of the body whorl of the shell." In my own collection there is a large white shell of this group; but I never could see the resemblance to a pelican's foot. I bought it in Key West over fifty years ago. Our North Atlantic moluscan fauna is said to contain four species of these shells, and *A. occidentalis* is one of them. This shell is only two inches in length, more or less; and so far as I am aware, the animal that lives in it is not as yet known to science. Up to the present time, we have only the broken specimens which the sea washes up on the banks of Newfoundland. Fish caught on that coast sometimes have them in their stomachs, and such specimens are always saved by those who are aware of their value to conchologists.

There is also a shell, or rather a small group of shells, called the "Ostrich-foot shells," which are found on the New Zealand coasts; they rarely exceed three inches in length, and are confined to the genus *Struthiolaria*, the type being *S. nodulosa*.

More or less nearly related to these Ostrich-foot and Pelican's-foot shells are the Spider and Scorpion shells of the genus *Pterocera*. Mr. W. Saville-Kent, F.Z.S., gives a very beautiful figure of a Scorpion shell on page 743 of the second volume of *The Living Animals of the World*, and from all appearances he had at hand the same species as the one shown in my two photographs of it in Figs. 39 and 40. They fall among the Conchs in classification, while their mollusks resemble those of Strombus. Some ten or more species have been described, and probably not a few others remain to be discovered by collectors and described by conchologists. These Scorpion shells belong in the great group of spirals, they being rendered very conspicuous through their having arranged around the aperture six great,

Scorpion Shell (Pterocera rugosa), from Mauritius. (Figs. 39-40)

pointed and curved spines, giving the entire structure, in the eyes of some, the appearance of a big arachnid or scorpion of some sort—a rather far-fetched resemblance. These shells are apparently entirely absent in our United States molluscan fauna,—the largest species of the group being the *Pterocera bryonia* of the Society Islands.

Sometimes the shells of these mollusks are called "spider shells," and they are known to occur in numbers in more or less shallow waters close to the shore line. Young specimens lack the curved, spinous, so-called spider's legs, or scorpion legs, as the case may be, and they do not begin to appear until the shell has attained fully half of its ultimate size. During these early stages these processes are hollow, being receptacles for filaments developed from the margin of the mantle.

Still other genera occur in this family *Strombidæ* of the Conch shell family. For example, we have the Little Beak shells arrayed in the genus *Rostellaria*, and the Little Screw shells of the genus Terebellum. This last contains *the* Little Screw shell or type of the group (*T. subulatum*), a most delicate and elegant little form, by some called the Lady-finger. Its shell bears scarcely any resemblance to other *Strombidæ*; and it is only through a study of the anatomy of the mollusk inhabiting it that taxonomers were enabled to refer it to its proper group. This species belongs to the molluscan fauna of the Philippine Islands and China, and collectors highly prize perfect specimens of it. It resembles an elongate olive shell, being a glossy white, faintly dappled with pale brown. It is a small species about two inches in length, and Miss Rogers gives us a figure of it in her book on shells, where she says of its mollusk that "the creature is shy and sensitive to disturbance. While taking observations, it is a strange-looking object with its one eye thrust out so far and waving about, while the pointed shell is held unsteadily in a vertical position. It takes fright easily and moves by a series of quick jumps. On one occasion a beautiful specimen leaped suddenly out of the hand of Mr. Hugh Cuming, the eminent English collector, as he was admiring it and congratulating himself upon getting one alive" (p. 122).

While the shells of the existing Mollusca constitute an enormous assemblage of different, and in some instances widely separated forms, we must not overlook the fact, hidden in certain parts of the earth's crust, there exists an array of *fossil* shells that represent the extinct types of former ages. Of these there are, too hundreds upon hundreds of different species, a small proportion of them being like certain existing ones. Through the studies of the palæoconchologists we have not only acquired a knowledge of the forms of these extinct shells, but the ancestry of their existing relatives has been traced in many instances, not to mention the important light they have cast upon the question of the age of the earth and stratigraphical geology.

Super-Conductivity of Metals at Low Temperature

It has been noticed that the electric resistance of perfectly pure metals disappears at the temperature of liquid helium, that is at 1.9° F. absolute or 490.1° below Fahrenheit zero. It was not found possible to obtain gold and platinum perfectly pure, and their resistance in liquid helium did not decrease indefinitely but remained at a very low constant value. Quicksilver can be obtained perfectly pure by distillation in vacuum, and showed a decrease in resistance down to 7.55° F. absolute, which corresponds to 1/500th of the resistance at the solidifying point of quicksilver. At this temperature there was a sudden drop that immediately reduced the resistance to one millionth part of the initial value, and at 3.25° F. absolute the resistance was barely one thousand millionth part of the initial. This condition the author called super-conductivity.

Tin and lead were also brought to the state of superconductivity. The critical temperatures being 6.85° and 10.8° F. absolute, respectively. It was found possible to send a current of 1,000 amp. per square millimetre through an extraordinary thin wire of quicksilver, and 560 amp. per millimetre through a lead wire without observing any heating effect or any difference in electric tension between the ends of the super-conductors. Experiments to produce magnetic fields of greater strength than 50,000 Gauss by means of coils of super-conductive wire failed. The super-conductivity of a double wire coil at 3.6° F. absolute was lost when the strength of the magnetic field rose above 1,000 Gauss, and the resistance became a definite value.

A lead coil with a resistance of 0.5 by 10-13 by 736 ohm. at a temperature of 3.24° F. absolute, was exposed to a magnetic field of 200 Gauss, and an induced current of 0.4 to 0.6 amp. was observed after the removal of the field. The current decreased 1 per cent. per hour and lasted four days before it disappeared. The current in such a coil disappeared immediately it was taken out of the liquid helium.—*Zeitschrift des Vereines Deutscher Ingenieure.*

Spectrum Analysis and Atomic Structure*

A Remarkable Application of the Quantum Theory

By Sir J. J. Thomson

Before opening his fifth lecture on "Spectrum Analysis and its Application to Atomic Structure," at the Royal Institution on Saturday, April 5, Sir J. J. Thomson, O.M., P.R.S., speaking with manifest emotion, said that lecturing in this place and on spectrum analysis, it was fitting for him to refer to the great loss science had sustained by the death of Sir William Crookes, one of the great leaders in the study of the subject they were discussing. Very nearly sixty years ago Sir W. Crookes had made one of the most striking applications of spectrum analysis which had led to the discovery of thallium, and working on uninterruptedly, until a few weeks ago, he had put forth a series of researches unsurpassed almost both as regards experimental skill and the importance of the results. Sir Joseph would only mention the discovery of the radiometer, one of the romances of science in the sense that a clue, which had appeared very remote, had been followed up until it led to the striking effects which Sir William had so often exhibited in this place. Sir Joseph further mentioned the study of the electric discharge through high vacua and the Crookes "dark space," and the important series of researches on the spectra of the rare earths when bombarded by kathode rays. Sir William had started as many new subjects as almost any physicist working in this country for the last century. He had that instinct which all great scientists must possess of being able to select the proper subject, and the power, too, of saying the first word on the subject, and it was the first word which counted a great deal in all subjects of physical investigation. The Royal Institution, whose audience he had delighted many times, and of which he had been Honorary Secretary for a considerable number of years, owed him great service. Sir W. Crookes was one who had increased and upheld the prestige of British science.

Turning to his subject, Sir Joseph stated that in the last lecture he had explained what was meant by the quantum theory with respect to their problem: whenever radiant energy was transferred into some other form of potential or kinetic energy, the transformation was not continuous, but took place by definite units, and when we transformed energy of other forms into energy of radiation, the energy disappeared by units, which represented multiples of the frequency of the radiation produced. He now wished to describe a remarkable application of that theory to the subject of spectrum analysis, which we owed to Dr. N. Bohr. Bohr imagined a hydrogen atom, the single electron of which described a circular orbit round a central positive charge, and he assumed the force due to that charge to vary according to the inverse square law. On that law, Sir Joseph considered, there was nothing to fix the orbit; given suitable velocity, the orbits might be of any radius, and the whole space round the positive charge might be filled with possible paths of the electron. The phenomenon of the light given out by hydrogen showed that this could not be so; such a complexity of paths should result in a continuous spectrum, and not in a series of lines. Sir Joseph himself had accounted for the necessary differentiation by substituting another law for the inverse square law. Bohr, he said, selected certain orbits by applying a certain principle which closely resembled the quantum principle, but was not really that principle itself. Bohr suggested that the only possible orbits were those in which the energy of the electron was bearing a definite ratio to the speed of rotation, and was a definite multiple of the frequency. That condition separated out an infinite number of orbits at definite distances apart. The energy was $\frac{1}{2} m r^2 w^2$, and Bohr's condition, that the ratio of the energy of the electron to its angular velocity was an integral multiple of a definite unit, gave the equation:

$$\tfrac{1}{2}\, m\, r^2\, w^2 = h\, p\, w\, /\, 2\, \pi,$$

where h was Planck's constant, p an integer, and $w/2\pi$ the frequency of the rotation if w represented the angular velocity. When we divided the equation by w, the equation changed into $m\, r^2\, w = h\, p\, /\, \pi$; in other words, all the possible orbits must have a moment of momentum represented by $h\, p\, /\, \pi$, and this moment increased by jumps, as p was first 1, then 2, &c. Combining this relation with the consideration that the electron was held in equilibrium by the attractive force of the positive electricity which was counterbalanced by the centrifugal force, we had $m\, w^2\, r = E\, e/r^2$, or $m\, w^2\, r^3 = Ee$. From these two equations we could find the values of both r and w, and the different p gave with the different r a series of radial positions for the electrons at separate distances from each other, as on Sir Joseph's own view. But there was this difference between the two views: Sir Joseph's radial distances were proportional to $1/p$ and proceeded in harmonical progression, while Bohr's distances increased with the square of p. Thus Bohr had one position at distance 1 from the center, the next at distance $2^2 = 4$, &c., and the position corresponding to a line of the 30th order would be at distance 900, so that the higher members of the series might be of more than atomic dimensions.

There was another principal consideration. Bohr's electron was assumed to describe orbits in definite times, but not to give out any radiations except when the electron was changing from one steady orbit to another. Innocent as that assumption might appear to be, Sir Joseph wished to point out, it involved great consequences from the dynamic point of view. By the electro-magnetic theory of light radiation-waves corresponded to the propagation of electric and magnetic forces. But if the orbital motion of Bohr's electron were not to produce radiation, it could not even produce magnetic force. For, if it did, that magnetic force would depend on the distance and the direction of the moving electron, and the force exerted by a particular electron at any point would be different from the force it would exert when it was at the opposite end of a diameter; thus the magnetic force at any point corresponding to a certain value of p would vary periodically. According to Maxwell's theory, however, the periodic variation of magnetic force must necessarily be accompanied by something which was indistinguishable from radiation. Thus, if we wished to retain the fundamental idea of the electro-magnetic theory, we should have to suppose that, somehow or other, the electron moving in its orbit did not give rise to any magnetic force.

Granting with Dr. Bohr, however, that radiation was not produced by the electron while describing a steady orbit, we had to see how he conceived radiations to arise. Bohr suggested that radiation occurred when the electron tumbled from one of its steady orbits into another, and that a quantum law held there: that the energy which the electron acquired in falling from one orbit to the other was transformed into radiation acording to a quantum law. Bohr's $h\,\nu$, then, was equal to the difference in the energy between the two orbits. In this way Bohr obtained an expression of the form $N(1/p^2 - 1/q^2)$, and not only the form of his equation was right, but the constant N was correct, and the lines of the Balmer series of hydrogen were reproduced with extraordinary accuracy. From the arithmetical point of view Bohr's theory was therefore unexceptional, and it had led to a great advance in spectroscopy—it was one of the great merits of theories that they led to extended investigations. But the theory was open to considerable difficulty from the physical point of view, and one of the difficulties was this: the frequency which corresponded to the lines did not correspond to the frequency of any electron in that system. Bohr's frequency merely depended on the energy which was transferred to it by dropping from one orbit to another. There was nothing in Bohr's atom in its normal state which needed to vibrate with the frequency of one of its lines. Sir Joseph referred in this connection to the sharpness of the lines of some absorption spectra. These cold vapor lines belonging to the principal series were so sharply defined that it was difficult to get away from the idea that they must have something to do with resonance. But the strong absorption could hardly take place in a system which had no period to correspond to it. Sir Joseph was not at all sure, in fact, what it was that Bohr supposed to vibrate, whether it was the electron itself or something associated with it.

Continuing Profesor Thomson repeated that the higher members of the hydrogen series of Bohr would correspond to electrons of very large orbits. Now these extreme lines were not, as a rule, seen in spectrum tubes, but were of frequent occurrence in stellar nebulæ, because, Dr. Bohr said, there was no room for their orbits in our tubes, while the very small gas pressure in the nebulæ left the electrons room for large orbits without interfering with one another. Lately, however, Merton and Nicholson had obtained these lines even at very considerable pressure, more than 30 mm. of mercury, provided that pressure were produced by helium. The effect of the neutral gases in bringing out lines in the ultra-violet had been observed by Liveing and Dewar years ago, and Merton and Nicholson had extended this research. It was difficult, moreover, to understand on Bohr's view why the region corresponding to the limit of the spectrum should not always appear bright. If the lines were excited by electrons falling in, and the higher lines were due to electrons tumbling in from great distances, at high velocity, the case would be that of the charged atom of an ionized gas moving about among many electrons; most of these electrons should produce the limit lines with great brightness; but that was not so. In both theories, however, Bohr's and Sir Joseph's, light emission would be due to the falling in of an electron into an atom which had been deprived of an electron.

Professor Thomson proceeded to show some experiments in which this falling-in was artificially prolonged, so to say, cases where atoms had been exposed to forces driving out electrons and the return of the electrons had been hampered in some way; they might, for instance, have difficulty in finding their way back into a solid substance, or the centers might be situated at great distances. Sir Joseph first exhibited a collection of glass tubes containing various sulphides capable of phosphorescing in different colors. The tubes were exposed to the bright light of the lantern, which was then turned out; some of the atoms were probably ionized, the light driving out the electrons and leaving the atoms positively charged; the glow which afterwards marked the return of the electrons to the atoms persisted for an appreciable time. This could also be shown with gases, when they were filled into spherical glass bulbs, and the bulbs were placed inside a primary coil and exposed to the high tension; the glow was not so brilliant and persistent as with the solid sulphides, yet it remained quite distinct with some gases. As regards the artificial acceleration of retardation of the return of the electrons, Sir Joseph referred to the experiments shown on other occasions by Sir James Dewar, who froze or "stored" the phosphorescence by immersing the substance in liquid air after exposing it to the radiation. Sir Joseph himself demonstrated the opposite effect; he hurried the phosphorescence up, hastening its disappearance, but concentrating it in a short space of time and making it momentarily brighter. For this purpose Sir Joseph used a discharge tube containing some calcium sulphide, mixed with manganese, in a kind of shovel; the shovel was attached to a narrower glass tube sliding in the outer tube and was fixed there air-tight by the aid of some wax. When the sulphide was bombarded by kathode rays, it phosphoresced in a beautiful green light; the luminosity soon faded. The tube was then heated sufficiently to melt the wax and to allow Sir Joseph to pull out the inner tube with the shovel; the sulphide was dark, but when the shovel was heated in a Bunsen burner the luminosity broke out again. Another tube shown by Sir Joseph contained neon, a little mercury and a few small glass bulbs (fixed) to enhance the friction between the glass, the mercury and the neon on shaking the tube; the ruddy light of neon was at once seen when the tube was shaken.

Coming back to the Bohr atom, Sir Joseph remarked that an alternative to the difficulty mentioned was that there should be two kinds of light: (1) A kind of light represented by Maxwell's equations, yet not producing the effects we associated with light, except in a Pickwickian sense; and (2) a kind of light produced by the falling-in of the electrons. The assumption of two kinds of light involved obvious difficulties, of course. The great point about the Bohr theory was the remarkable agreement between his values and the frequencies observed. The lecturer was not inclined to lay too much stress on that agreement, however. In the Bohr atom all the electrons were rotating, and the equilibrium was between the central attraction and the centrifugal force. In Sir Joseph's atom the electrons were at rest and occupied positions at which the electric force vanished; the electric force, which he assumed, did not vary with the inverse square of the distance inside the atom, and when not obeying that law, it was accompanied by a magnetic force. The magnetic force determined the vibrations which gave rise to the radiations, and if we assumed a simple relation—further explained, Sir Joseph mentioned, in The Philosophical Magazine for April, 1919—between the electric and magnetic forces, his views led to Planck's law and gave a physical concept for the quantum theory in the sense that the frequency of light was proportonal to the work which had to be done in order to remove

*From *Engineering* (London).

the electron from the atom. How was that to be understood? Suppose the hydrogen atom to have been deprived of its electron. Falling back into one of the equilibrium positions, the electron would twist round the line of electric force and, while twisting, would radiate and give out energy, the energy being that which the electron had acquired by falling-in from the outside. This assumption as to the connection between the magnetic and the electric force now made that energy proportional to the frequency of vibration in that place; thus the energy transformed into radiation would be proportional to the frequency, and we got a kind of quantum law. Then take the converse case, the transformation of radiant energy into the energy of separating the electron from its atom. Let light fall upon an electron, and let the vibration periods of the light and of the electron be the same; the electron would be excited by resonance and would absorb energy. The amount of energy absorbed might be sufficient for the electron to be shot out; in that case the energy absorbed would be equal to the energy of falling-in, and there would again be a quantum relation. But supposing the energy be insufficient for expelling the electron; there would only be conversion of light into energy of the same period, a transference leading to a scattering of light, without transformation of energy from one form into another; the quantum relation would again hold, however.

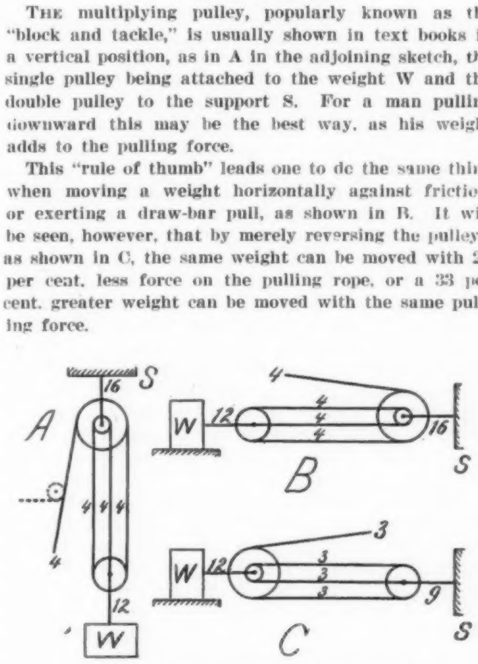
Whatever view we accepted as to the excitation of luminosity we should want the ejection of an electron, and the work required to eject the electron from the atom was therefore a fundamental quantity in the whole theory. We could not hope to excite luminosity unless we had enough energy to expel the electron. We should therefore expect to observe a sharp demarcation between the luminous state and the non-luminous state in cases where we were able to adjust the energy, and that was a well-known experimental phenomenon. In his demonstration, Sir Joseph used a vacuum bulb consisting of a tube widening out into a bulb, at the end of which was the anode; the kathode was a tungsten filament joined to a special heating circuit and surrounded by a cylindrical sheath of copper, the kathode proper, which also shut off the glow of the filament—a bulb of the kind used as valves for radiotelegraphy. At first there was only a faint general luminosity. As the resistance in the filament circuit was cut out, the emission of electrons from the hot tungsten increased, and suddenly a bluish glow became visible in the space between the two electrodes; the appearance of the glow marked the moment when the stream of electrons carried sufficient energy to knock out the electrons from the gas atoms. The exact measurement of that energy, Sir Joseph continued, then was a matter of great theoretical importance which had attracted a great deal of attention of late, and Sir Joseph wished to refer to the interpretation of the results obtained. It was usually assumed that the energy to be given to the electron should be equivalent to the work done when the electron moved from one place to another. That was not necessarily so, however. If we wanted to move a load up an incline, say from A to B, it all depended whether the road A B were straight or not. If straight, then the work was merely that corresponding to lifting the load through the level difference between B and A. If, however, the road to B led *via* a hill C, we should have to do more work, though we could get back part of the energy afterwards when the load was sliding down hill on the path C B; to reobtain energy we had first to give it in any case, however. In such a case the electron would come out with a high velocity, and there was considerable evidence that, in certain instances, the electron was expelled with a definite velocity. The electron did not merely trickle out of the atom, but shot out with energy of a finite amount. A solid bombarded by kathode rays gave out rays of its own, secondary rays. The speed of the secondary electrons did not depend upon the speed of the primary ejecting electrons; we might increase the speed of the primary electrons considerably without altering the speed of the secondary electrons. That secondary speed seemed to be characteristic of the material, though it did not vary much from one substance to another. But Sir Joseph's point was this: when we measured the energy required to ionize a substance, *i. e.*, to drive out the electrons, we ought to be sure that we did not do more than drive them out. We ought to make sure that we did not first mount the hill C on our way to B, and thus cause the electron to be ejected with a finite velocity. That point might be at the root of the difficulty which some experimenters had experienced in calculating the energy involved. One of the most reliable methods of conducting these measurements made use of the radiotelegraphic valves above mentioned. When the current, passing through gases, was plotted as ordinate against the electromotive force as abscissa with the aid of these valves and other appliances, the current curve first rose steadily up to a certain potential and then continued to rise at a more rapid rate. That sudden increase in the current could be accounted for if, at that particular stage, another electron were knocked out of the gas so that an artificial increase of electrons was produced, so to say. The different methods yielded different results, and those obtained with the aid of the valves seemed to be the most consistent. A great deal of work had lately been done with valves for military and commercial purposes. When the energy required to ionize a gas had been deduced from such experiments, helium had been found to be the most difficult gas to ionize, requiring 20.1 volts. Mercury could be ionized by 10 volts, even by 5 volts, according to some experimenters. Nitrogen, strangely enough, had given the high value of 17 volts, higher than hydrogen, in some valves. In some valves an abnormal potential had been observed which did not correspond to that for any known gas. The valves in question had been made with a kind of tungsten which was not satisfactory. When a good tungsten was substituted, the peculiarity was no longer observed, and it had so far been impossible to trace the cause of the anomaly.

Text Books vs. Practice

By Carl Hering

The multiplying pulley, popularly known as the "block and tackle," is usually shown in text books in a vertical position, as in A in the adjoining sketch, the single pulley being attached to the weight W and the double pulley to the support S. For a man pulling downward this may be the best way, as his weight adds to the pulling force.

This "rule of thumb" leads one to do the same thing when moving a weight horizontally against friction, or exerting a draw-bar pull, as shown in B. It will be seen, however, that by merely reversing the pulleys, as shown in C, the same weight can be moved with 25 per cent. less force on the pulling rope, or a 33 per cent. greater weight can be moved with the same pulling force.



Pulley puzzles in which practice seems to reverse theory

This reversal of the pulleys will have the same effect in A when the pulling rope is horizontal (shown in dotted lines), as it frequently is in practice. In general, and for all combinations of pulleys, to obtain this advantage, attach the blocks so that the pulling rope leads to the weight and not to the support; or, in other words, pull from the weight and not from the support, text-books notwithstanding.

Others besides the writer may have found this out in practice, but it does not seem to be as generally mentioned in text-books as it should be, and may therefore not be commonly known.

On the other hand, the practical man may also commit errors if he follows rules blindly and does not do his own thinking. For instance, in the case shown in B he says: "Stand on the weight while you do the pulling;" in other words, if you are moving a stalled or wrecked automobile, for instance, get on the car yourself. It is true that this will give the same advantages as in C if the man's weight can be assumed to be negligible; but in C no such assumption is necessary, and as his weight generally would add an appreciable load, especially when there is any vertical lifting done, C is always the better way.—*Journal of the Engineers' Club of Philadelphia.*

Ship and Cargo in One

In years gone by we have illustrated various huge rafts of lumber which were assembled into a general cigar form and towed, sometimes over routes several hundred miles in length to their port of destination. In those rafts the lumber was shipped in the rough, with the bark on the logs. In building a raft, a cradle was first erected of the form which the raft was to take, and then the logs were assembled within it and tied together with heavy chains drawn up tightly by turnbuckles.

The accompanying illustrations show a craft which is certainly unique in the annals of naval architecture. It may be designated as a raft of ship form; for the bottom, sides, bulkheads, decks, etc., are built of square, sawn timber measuring 12 inches square and up in section. As our contemporary, The *Illustrated London News*, to whom we are indebted for our illustrations, says of this vessel, "The cargo is the ship, and the ship is the cargo."

The craft which is being constructed in British Columbia by Messrs. Vickers, consists of five million feet B. M. of timber in the form of great sticks of Douglas fir, hemlock, and cedar from the forests of the Pacific slopes. The sectional view shows that the floor of the ship is built up of six layers of timber placed alternately in the longitudinal and transverse position. On this are built up the flat sides and the wedge-shaped bow and stern. The usual decks are provided and they, also, are built of heavy timber. There is a forecastle deck forward and a poop aft. Under the forecastle deck are the stores, chain-locker, etc., and under the poop are to be found the engine-room and the accommodations for the crew. Upon the poop aft of the smoke-stack is a chart-room and captain's room. The ship is driven by heavy-oil engines carried upon the main deck, and the power is transmitted from them to the twin propeller shafts by means of a vertical shaft and gearing, as shown in the sketch. The vessel is divided by transverse bulkheads, and the whole structure of the ship is held together by long and heavy steel screwbolts.

The length of this remarkable craft is 250 feet, its beam 60 feet, and its depth 36 feet. The displacement will be about 9,000 tons. She will make but one voyage from British Columbia to England, where, upon arrival, she will be unbolted, and the materials will be used to meet the serious shortage of timber in that country.

Tin-Mining in the Dutch Indies

Alluvial tin-mining with hand-working has been carried out in the island of Billiton for more than 60 years; but machinery has been gradually introduced during the last decade as the surface deposits became worked out. Large hydraulic jet dredgers capable of working strata 50 to 80 ft. below the surface were at first installed, but it was found that smaller and less expensive pump-dredgers could be used with equal advantage and constituted a substitute for hand labor, which could not be profitably employed at a greater depth than 13 ft. Successful installations of this type are at work in large numbers.

One company alone has 13 sand-pumping plants, and 3 hydraulic dredgers. The latter direct strong jets of water against banks of low-grade stanniferous ore, yielding in some cases three-quarters of a pound of tin per cubic yard. The water, sand, and ore flow towards the pumping plant, which discharges on large platforms having sufficient slope to retain the ore only.

The following machinery was at work on the islands in 1917:

68 portable engines with a total of 2,370 h.p.

448 oil engines with a total of 4,347 h.p.

72 steam boilers with 14,000 square feet heating surface.

168 centrifugal pumps.

74 pulsometers, and a number of electric motors of 2 to 110 h.p.

The number of Europeans was 39 in 1905, increasing to 190 in 1917; but the labor force dwindled from 3,818 to 2,013, thus an increase of 1,900 h.p. in the plant caused a reduction of 1,800 natives, or roughly one per additional h.p. installed.

The production of tin which in 1905 was only 3,930 tons, increased to 6,200 tons in 1917, and to 6,800 tons in 1918. The 1917 output was obtained from a total of 6,500,000 cubic yards of gravel, yielding an average of 2,375 lbs. of tin per cubic yard.

Particulars are given of a number of installations. An hydraulic dredging plant of 260 h.p. employed 2 in. and 3 in. jets, with a head of 100 to 165 ft. of water, and raised the sludge 57 ft. 6 in. by centrifugal pumps. The total quantity raised in 1916-17 was 1,013,500 cubic yards, against 264,000 cubic yards in 1909-10, and the cost of pumping was £25,850, equal to 10.15 d. per cubic yard. The plant produced 715 tons of pure tin, and the cost of production including smelting, refining, and all general charges was £94 10s. 0d. per ton of tin, while the cost in 1909-10 for the same plant working with 106 h.p. was £128 per ton.

The plants vary in efficiency and economy according to general conditions and the richness of ore, but the above figures are fair average working costs of large plants.—*De Ingenieur.*

Influence of Magnetic Field on the Initial Phase of the Electric Discharge

(*Concluded from page 371*)

In the particular case of the influence of the field on the potential of discharge, we must also take into consideration, besides the magnetic field, the electric field due to the difference of potential of the electrodes. For certain reasons it can be predicted that the influence of the magnetization is most evident when the two fields lie in a rectangular direction. M. Righi's experiments prove, in fact, that the magnetic field causes the potential of discharge to be lowered precisely at the moment when it lies in a direction perpendicular to the lines of electric force, i. e. when it tends to prevent the positive ions as well as the electrons from moving in the direction which runs from one electrode to the other as required by the mechanism of the discharge. There can be no doubt according to M. Righi that the current explanation is insufficient and that it is necessary to assume a special action of the field tending to favor the discharge which would be magneto-ionization.—*Revue Scientifique* (Paris).

A Unique Form of Prehistoric Pottery

(*Concluded from page 377*)

was used as a receptacle for sacred water. It is not unusual for the Hopi priests today to make long pilgrimages to distant springs to procure water to use in their rites. The medicine vessels of Hopi priests are, however, smaller and simpler than that here considered, although some of these sacred vessels are furnished with handles. The size of the two members of the prehistoric vessels are about the same; both are almost spherical, slightly flattened on their upper side where they are decorated with parallel lines distributed in four blocks. Both have an unusual feature in prehistoric pottery—a concave basal depression. This unique form of pottery belongs to the black-and-white ware which is regarded as archaic and characteristic of the most ancient pueblo ruins.—J. W. Fewkes, in *Journ. Wash. Acad. Sci.*

The Color of Water—I

(*Continued from page 375*)

"The third method was by sinking white and different colored surfaces under water, and noting the change which took place in the colors. The colors selected were red, yellow, and purple. It was found that these colors when seen through the water changed in the same way as when seen through a blue transparent medium, such as a piece of glass. The white changed to blue. The red darkened very rapidly as it descended, a very small depth of water being sufficient to destroy all the color. At a depth of about 2 m. a very brilliant red was so darkened as to appear a dark brick red. Yellow changed to green by the water absorbing the red component of the yellow. An orange, as it sank in the water, appeared to become more and more unripe, while a lemon became quite green. The purple surface quickly changed to a dark blue or violet by the selective absorption of the water. These changes, being all due to the cutting out of the red component of the colors, showed the water to have a selective absorption for the rays of the red and of the spectrum. If the water had been colored blue by selective reflection, then those test colors would all have appeared deficient in blue when sunk in the water, as the fine particles would reflect and scatter the blue rays. Experiments are described which show that when these colors are sunk in water colored blue by reflection from small particles, white changes to yellow, while yellow simply deepens in color, and purple grows redder.

"All these different methods of experimenting show this water to be a blue transparent medium, and that it acts in the same way as a solution of a blue salt or as a blue tinted glass. It is then shown that this selective absorption theory is not enough to account for the different color phenomena seen in water. A piece of blue glass or a blue solution have but little color when viewed from the side on which the light is falling, and it seems certain that light will penetrate pure water till it is all absorbed, and the water will look dark and colorless. Something more, and that of great importance, is obviously necessary to explain the different color phenomena seen in different waters, and in the same water at different times.

"If the water of the Mediterranean, when brilliantly colored, is examined by means of a concentrated beam of light, it is found to be full of fine solid particles in suspension. It is shown that it is to this dust of the sea—so to speak—that the Mediterranean owes its fine and varied coloring. The particles of this aquatic dust are large, and reflect not only the blue rays, like the supposed particles of the selective reflection theory, but they reflect rays of all colors, and the water, by its selective absorption, strikes down the red rays, and only the blue rays are reflected to the surface and to the eye. These solid particles determine the brilliancy, and the selective absorption of the water determines its color. The color and the amount of the suspended particles is then considered. It is shown that the color of the particles will have a marked influence in the appearance of the water. If the particles are yellow—sand particles, for instance—then a blue colored water will appear to be green, as the light reflected by the yellow particles is deficient in the rays of the violet end of the spectrum.

"In the Mediterranean the solid particles are whitish and all the different color phenomena are easily explained by the different amounts of the reflecting particles at the different places. Where the color is deep blue there are few particles in the water, and but little light reflected; and, further, the light passes through a great amount of water, and undergoes a great amount of selective absorption before it is reflected to the surface and to the eye. But if there are many particles in the water much light is reflected, and the color is chalky blue-green, as the light does not pass through so great a depth of water, and is therefore not so deeply colored, nor has it so many of the green rays cut out as in the water where the particles are few and far separated.

"Color experiments on a small scale with a solution of Prussian blue and a fine white powder are described. If the solution of Prussian blue is placed in a vessel, the bottom and sides of which are dark and reflect no light, then the colored solution appears dark and colorless; but if a little of the white powder is added then the solution at once becomes brilliantly colored. By varying the amount of the powder in the water all the varied color effects of the Mediterranean can be reproduced, a little powder causing the solution to appear deep blue, and as more power is added the brilliancy of the water increases, and its color changes from blue to chalky blue-green.

"The presence and the abundance of white reflecting particles is shown to be a characteristic of all finely colored waters, and the wave-washed shores of the Mediterranean are shown to be the factories in which are prepared its reflecting particles. The waves, as they beat on the shore, grind up the stones and rocks, and stir up a great amount of fine whitish solid matter, which gives the water along the shore a milky appearance.

"With the assistance of these whitish particles, we understand how it is that the brilliant blue-green of this sea depends so much on the continuance of sea-breezes. The longer the wave-mills have been at work the more fine powder has been produced along the shore, and more time given for the particles to be carried seaward, by the wave-mixed and wind-driven waters, and the blue-green which only extended in a narrow band along the shore, when the wind began to blow, is, after a few days of inshore wind, seen to extend far to sea. We also understand how it is that the color near shore is so brilliant and so much greener than outside. Near the shore there is a greater quantity of white solid matter in suspension; there is therefore more light reflected, and further, the light does not penetrate through so great a depth of water, and has not so much of the light of the red end of the spectrum cut out, and therefore looks greener than the water outside, the light from which has to penetrate a greater depth of the absorbing medium. The blueness and beauty of the Mediterranean would thus appear to be due to the blue transparency of its waters, coupled with the presence of white reflecting particles, and the variety in its coloring to the amount of the suspended particles at different places and at different times.

"From this we see the important influence which the geological formation of the shore has on the appearance of the water of a sea, as it determines the nature of the solid suspended particles. This is beautifully illustrated by the difference of coloring in the Mediterranean at Mentone and at Cannes. At Mentone, limestone is everywhere abundant along the shore, and this limestone, when ground up by the waves, produces an extremely fine and white powder, which mixed with the water, causes the sea at Mentone to be far more brilliantly colored than it is at Cannes, where there is but little limestone, and the shore is almost everywhere covered with sand, the débris of the surrounding rocks.

"In the experiments in the Mediterranean it was found that the solid particles were so abundant that they prevented the sun's rays penetrating in a direct line to any great depth. This was shown by the illumination of the white surface placed at some distance under the water, and seen through the empty tube, being the same, whether the surface was turned towards the sun or away from it. It was also shown by the fact that at a depth of 6 m. these solid particles were found to reflect about as much light as a white surface did. These solid particles act like a fog, and, while they stop the light penetrating in a direct line, yet allow it to penetrate much further by internal reflection. The sun's rays get entangled—so to speak—among the particles, and are reflected from particle to particle, becoming a deeper blue with each reflection, so that the particles become illuminated with blue light. From this it is obvious that the more transparent the water, and the greater the reflecting power of the particles, the more deeply colored will the water appear.

(*To be continued*)

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Table of Contents

PAGE